FREQUENCY MEASUREMENTS

AT RADIO FREQUENCIES

BULLETIN 11 · GENERAL RADIO CO., CAMBRIDGE, MASS.

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GENERAL RADIO COMPANY
CAMBRIDGE, MASSACHUSETTS

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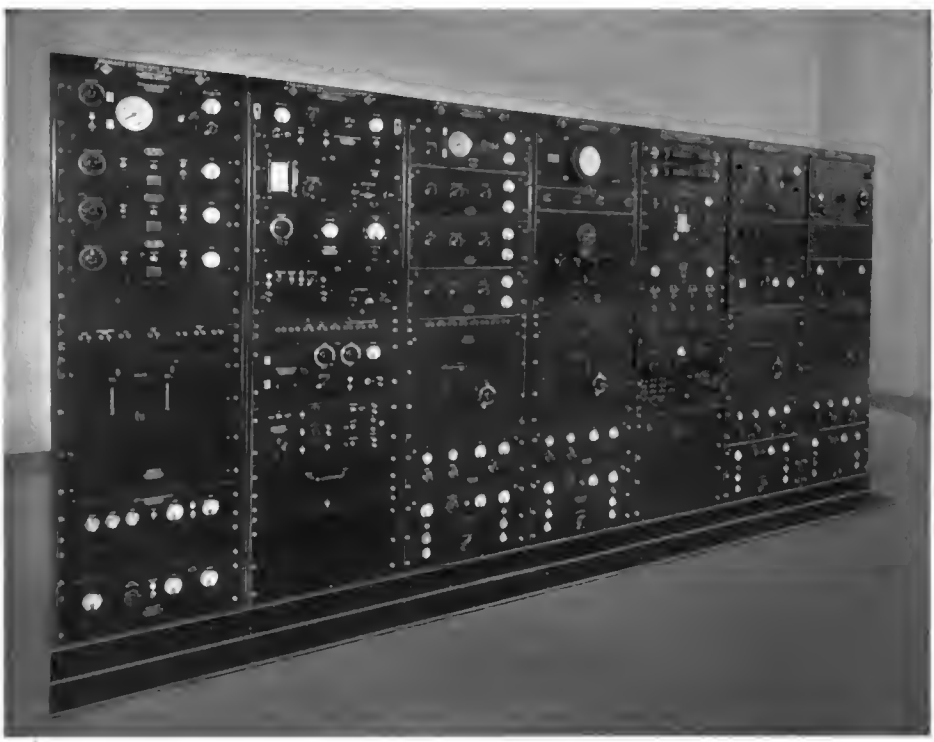


The frequency standards room at the General Radio Company. The standardization equipment consists of a number of standard-frequency oscillators with means for intercomparing them and plotting a continuous record of frequency drift. Standard frequencies from this equipment are distributed to the various laboratories in the General Radio building for use in development work and testing. The two racks at the extreme left contain a complete frequency-measuring system consisting of a CLASS C-21-H Standard-Frequency Assembly and interpolation equipment

PART I. METHODS

FREQUENCY AND TIME

Frequency, whether in electrical or mechanical systems, is the time rate of recurrence of cyclical phenomena. It is inseparable from the concept of time, and the two are related by the expression

$$f = \frac{1}{T},$$

where f is the frequency and T is the time of one complete cycle, usually called the *period* or the *periodic time.*

In order to establish a standard of frequency, it is obviously necessary first to establish a reliable standard of time. A cyclical system having a substantially constant rate can then be set up, which, when referred to the standard time interval, becomes a standard of frequency.

The fundamental standard upon which all measurements of time and frequency are ultimately based is the rotation of the earth in space. The duration of one complete revolution of the earth on its axis is our fundamental standard of time, the sidereal day. In the determination of standard time, observations are made of the passage of certain fixed stars across one of the earth's meridians. The interval between two successive transits of one of these stars across the observer's meridian is a sidereal day.

The practical unit of time is the solar day, which is determined by the passage of the sun over a given meridian. As a result of the eccentricity of the earth's orbit about the sun and the inclination of the earth's axis in its orbit, the solar

FIGURE 1. The time signal room at the U. S. Naval Observatory. At the extreme left is a General Radio Standard 1-kc Generator from which is driven a synchronous-motor clock. The chronograph records the received radio time signal in terms of standard time as indicated by the clock. The transmitting clock, which was built by the Naval Observatory, is provided with an adjustment for bringing the received signal into exact synchronism with standard time

day varies in length, and, for practical reasons, the working standard of time is the mean solar day or the average length of a solar day throughout a year. The mean solar day bears a fixed and known relation to the mean sidereal day.*

In practice, the interval between star transits, which determines the sidereal day, is recorded in terms of the readings of precise astronomical clocks. Time, as determined by these clocks, is then made generally available by means of time signals over both wire- and radio-communication channels, and standards of both time and frequency can be compared with these signals.

In general, timekeeping devices, such as clocks, are standards of both time and frequency. If the pendulum of a clock beats seconds, the frequency of the pendulum is one-half cycle per second. By means of its escapement, the pendulum operates a clock train which is so geared that, when the pendulum frequency is exactly one-half cycle per second, the clock keeps true time. The clock indication can be checked periodically against star sights or radio time signals and its rate computed. The system thus established is not only a timekeeper but also a means of determining the pendulum frequency. If, for example, the clock gains two seconds per day, the average frequency of the pendulum is

$$\frac{86{,}402}{86{,}400} \times 0.5000000 = 0.5000116$$

cycles per second, since there are 86,400 seconds in a mean solar day.

This method of frequency determination is used in establishing a primary standard of frequency.

*The length of the sidereal day, sometimes called the apparent equinoctial day, is subject to a slight variation. For this reason, many observatories use mean equinoctial time in computing the rates of precision clocks.

THE PRIMARY STANDARD

Since radio communication deals with frequencies considerably higher than one-half cycle per second, the pendulum clock just described is hardly a suitable standard for use in measurements at radio frequencies. The useful radio spectrum extends from audio frequencies up to several megacycles, and a practical frequency standard should be capable of furnishing standard frequencies over this entire range.

For this reason, and because of certain design considerations, the frequency of the working standard is usually in the low radio-frequency range.

Figure 2 is a block diagram of a primary frequency standard. The working standard is an oscillator the frequency of which is extremely stable. Associated with the oscillator is a timing system, which operates as a counter of the number of cycles executed by the oscillator in a given time interval. This counter, which, for convenience, may operate a clock train, can be so geared that, when the frequency of the oscillator has a specified value, the clock indicates true time.

The timing system is the distinguishing characteristic of a primary frequency standard. A stable oscillator does not in itself constitute a primary standard unless a timing means is provided.

TIMING

By comparing the reading of the clock with a standard time interval, a measure of the oscillator frequency is obtained. The mean frequency f_0 is given by this expression,

$$f_0 = \frac{\text{Total number of cycles in time interval T}}{\text{Time interval T}}$$

and in terms of the clock indication,

$$f_0 = \frac{\text{Clock reading for time interval T}}{\text{Time interval T}} \times \text{nominal oscillator frequency.}$$

In order to justify the use of a timing system, the frequency of the oscillator must be so nearly constant that the difference between its mean frequency and its instantaneous frequency is negligibly small, since otherwise the mean frequency obtained by means of the time comparison would have no significance.

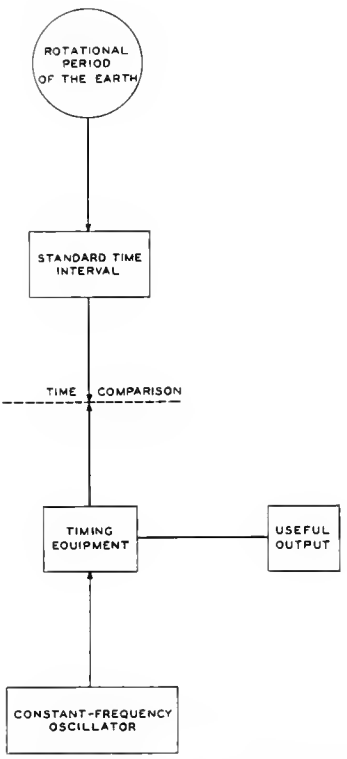


FIGURE 2. Functional diagram for a primary standard of frequency. The frequency of a primary standard is measured by direct comparison with the rotational period of the earth. Hence any primary standard will consist of a constant-frequency oscillator (such as a pendulum, or a crystal) and some means for counting the number of its oscillations in a given standard time interval. For a detailed example of a practical primary standard, see Figure 7

FREQUENCY MULTIPLICATION AND DIVISION

Since a single-frequency standard has little value for measurements over a wide frequency range, a practical standard-frequency assembly includes equipment for producing a multiplicity of other frequencies from the standard-frequency oscillator. In the diagram of Figure 2, these frequencies are included in the portion labeled USEFUL OUTPUT. They are usually produced by a process of frequency division and multiplication, which requires comparatively simple equipment.

Reduced to its elements, the system for deriving these frequencies operates as shown in Figure 3. For frequency division, some form of relaxation oscillator is generally used, such as the multivibrator. An oscillator of this type is distinguished by its susceptibility to control by the introduction into its circuit of a voltage whose frequency corresponds approximately to its fundamental or a low-order harmonic. Under this condition, the frequency of the relaxation oscillator locks into step with the controlling voltage and bears an integral relation to it.

If the frequency of the working standard is f_0, a frequency divider controlled by it will have a fundamental frequency $\frac{f_0}{m_1}$, where m_1 is a whole

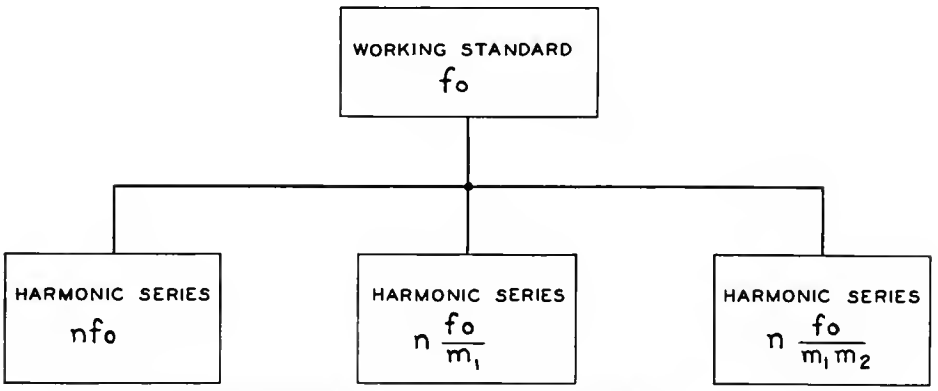


FIGURE 3. Functional diagram of a system for frequency division and multiplication

number. This unit can, in turn, control another similar instrument to divide the frequency by another whole number m_2, giving a total reduction in frequency of m_1m_2. This process can, of course, be continued with more stages of frequency division, if desired.

From each of these standard frequencies f_0, $\frac{f_0}{m_1}$, $\frac{f_0}{m_1m_2}$, etc., an infinite series of frequencies can be derived by the generation of harmonics. A relaxation oscillator has an extremely distorted waveform and its output contains hundreds of harmonics. This is, in effect, a process of frequency multiplication.

By means of this process, a great number of standard frequencies, each of which is known with the same accuracy as the source itself, can be produced from a single-frequency source, and, by properly choosing the factors by which the source frequency is divided, these derived frequencies can be made to cover a large part of the communication-frequency spectrum.*

*J. K. Clapp, "Universal Frequency Standardization from a Single Frequency Standard," *Journal Optical Society of America and Review of Scientific Instruments* XV, 25, July, 1927.

SECONDARY FREQUENCY STANDARD

A secondary standard of frequency is a calibrated instrument, the frequency of which has been previously determined by comparison with a primary standard. While, broadly speaking, the term *secondary standard* can be applied to any calibrated frequency-measuring device, it is commonly used to refer to a piezo-electric oscillator with which no means of timing is provided.

In commercially available secondary standards, multivibrators or other means of producing harmonic frequencies are usually provided.

For a large part of frequency standardization and frequency measurement work, the lack of a timing system is not important. Accurate standard-frequency radio transmissions are now available, in terms of which the secondary standard can be rated or adjusted. Since these transmissions are monitored against a highly accurate primary standard, an accurate measurement of the frequency of the secondary standard can be made frequently.

The frequency can be readjusted if any drift has taken place.

INTERPOLATION METHODS

The measurement of frequency using a harmonic-frequency standard consists essentially of measuring the difference between the unknown frequency and the nearest standard-frequency harmonic.

In Figure 4 is shown an unknown frequency f_x, lying between f_1 and f_2, which are the nth and the $(n+1)$th components of a harmonic series. Since the frequencies f_1 and f_2 are known, the problem resolves itself into the measurement of one of the frequency intervals A or B. The unknown frequency f_x is determined by adding A to f_1 or by subtracting B from f_2.

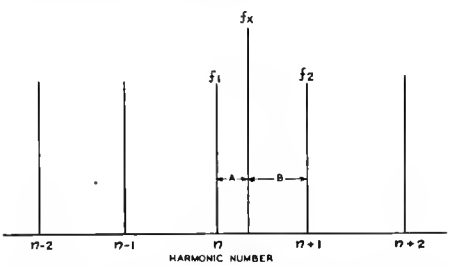


FIGURE 4. Diagram showing the relation between an unknown frequency and a standard harmonic series

Outlined here are two general methods of performing this interpolation.

I. DIRECT-BEATING METHOD

In this method, the unknown frequency and the standard harmonic series are impressed on a vacuum-tube detector, and the resulting difference frequency is measured by comparison with a calibrated oscillator. If a 10-kilocycle harmonic series is used, this beat frequency is never greater than 5000 cycles, permitting the use of an audio-frequency oscillator.

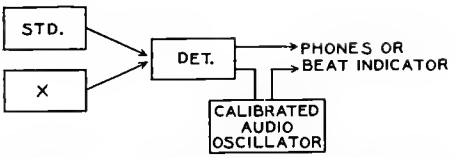


FIGURE 5. Functional diagram showing the operation of the direct-beating method

II. DIRECT-INTERPOLATION METHOD

The second method involves the use of a radio-frequency oscillator having a scale which varies linearly with frequency. This linear scale is used to interpolate directly between the two standard frequencies to locate the unknown. Figure 6 shows how this is accomplished.

If the oscillator is successively adjusted to zero beat with the unknown frequency f_x and with each of the standard frequencies f_1 and f_2, between which f_x lies, three dial settings S_x, S_1, and S_2 are obtained. Since the frequency intervals are proportional to corresponding scale intervals,

$$\frac{f_x - f_1}{f_2 - f_1} = \frac{S_x - S_1}{S_2 - S_1}$$

and

$$f_x = f_1 + \frac{S_x - S_1}{S_2 - S_1}$$

or

$$f_x = f_2 - \frac{S_2 - S_x}{S_2 - S_1}$$

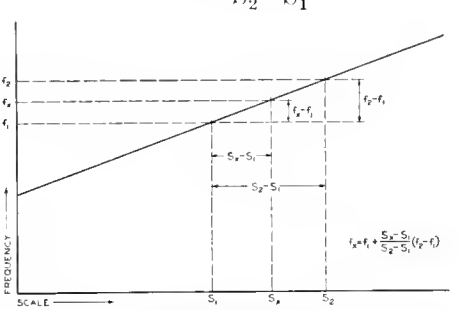


FIGURE 6. Plot of frequency vs. scale reading of a linear scale oscillator

CLASS C-21-H STANDARD-FREQUENCY ASSEMBLY

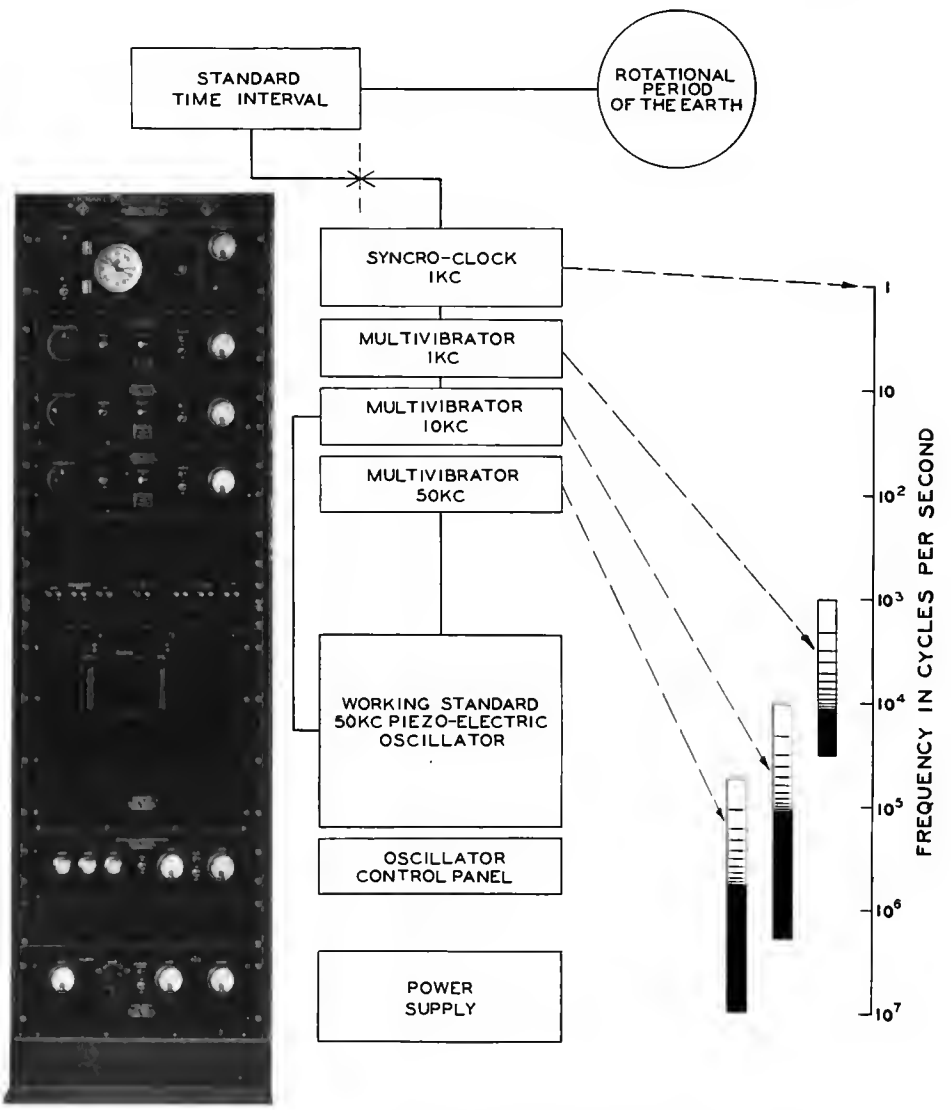


FIGURE 7. The CLASS C-21-H Standard-Frequency Assembly with functional diagram. The constant-frequency oscillator or working standard is a 50-kc piezo-electric oscillator. The 10-kc and 1-kc multivibrators, under control of the working standard, supply a 1-kc voltage for operating the syncro-clock. These three units make up the timing equipment by means of which the number of oscillations of the working standard is counted over the standard time interval. Each multivibrator is also a source of harmonic frequencies, furnishing the useful output of the assembly. The three spectra show the frequency distribution of the voltage from each unit

PART II. EQUIPMENT

CLASS C-21-H STANDARD-FREQUENCY ASSEMBLY

The CLASS C-21-H Standard-Frequency Assembly is the reduction to practice of the principles outlined on pages 5 to 8. This assembly is a practical frequency standard system designed for use in laboratory and commercial installations. It supplies hundreds of standard frequencies between one cycle per second and several megacycles, each known to better than five parts in ten million (0.00005%). The functional arrangement together with the photograph of this assembly is shown in Figure 7.

The frequency is determined by comparison with a standard time interval, usually by means of time signals which are transmitted by radio from the principal astronomical observatories of the world. The timing device is a 1-kilocycle synchronous-motor-driven clock which, when the driving frequency is exactly 1 kilocycle, indicates true mean solar time.

This 1-kilocycle frequency is derived from a highly stable piezo-electric oscillator, operating at a frequency of 50 kilocycles. In order to reduce this frequency to 1 kilocycle for driving the clock, two multivibrators are used, one of which divides the standard frequency by a factor of 5, and the second of which further divides it by 10, making a total reduction of 50 to 1. In addition to operating as a frequency divider, each of these multivibrators generates a harmonic series, as indicated in Figure 7. A third multivibrator, operating at the crystal frequency, produces harmonics of 50 kilocycles.

The 1-kilocycle harmonics furnish standard-frequency points in the audio-frequency range which can be selected by filter circuits and amplified if necessary. The 10-kilocycle series is easily usable up to about 4000 kilocycles. Above this frequency the fractional separation between harmonics is extremely small, and more elaborate methods of detecting the harmonics may be necessary. Harmonics from the 50-kilocycle multivibrator can be utilized by heterodyne methods up to several megacycles. The exact limit of their useful range depends somewhat on the sensitivity of the apparatus used to detect them. At extremely high radio frequencies an auxiliary oscillator can be used, the fundamental of which is adjusted in terms of the frequency standard at, for instance, 1000 kilocycles. The harmonics of this oscillator at 1000-kilocycle intervals can then be used for frequency standardization at the higher frequencies where the output of the standard cannot be used directly.

A contact closing once a second is provided on the synchronous clock unit. The time of occurrence of this contact is adjustable over a range of one second.

FREQUENCY STABILITY

Since all the output frequencies are controlled by a 50-kilocycle piezo-electric oscillator, the frequency stability and accuracy of the output are dependent entirely upon the design and construction of this oscillator. The factors affecting the stability of a piezo-electric oscillator are identical with those which influence other types of oscillators. The most important of these are temperature, operating voltages, and structural changes in the vacuum tubes and other circuit elements. The TYPE 690-B Piezo-Electric Oscillator used in this assembly has been designed to reduce to a minimum

the effects of all possible factors affecting the frequency.

The quartz bar and its mounting are designed to have low decrement and low temperature coefficient. In addition, a two-stage temperature-control system* is provided by means of which the temperature of the quartz bar is held to within 0.01 degree Centrigrade of its normal operating temperature. Variations in frequency due to temperature variations have been reduced to a few parts in one hundred million.

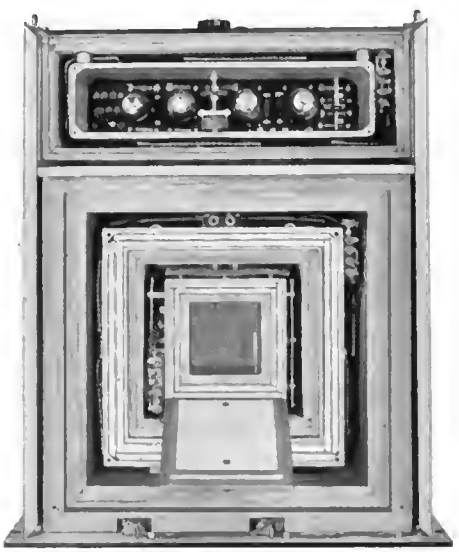


FIGURE 8. Inside view of TYPE 691-B Temperature-Control Unit

The oscillating circuit is of new design and operates the quartz bar at, or very near, its true resonant frequency. This circuit is the most satisfactory thus far devised for use with low-frequency quartz bars. Changing vacuum tubes and operating voltages have an entirely negligible effect on the frequency. The oscillator circuit elements are mounted in a third temperature-controlled chamber.

*J. K. Clapp, "Temperature Control for Frequency Standards," Proc. I. R. E., Vol. 18, No. 12, December, 1930.

FREQUENCY DIVIDERS

The multivibrators, which are used to divide the frequency of the working standard in order to produce a lower frequency for driving a synchronous-motor clock, are relaxation oscillators in which the uncontrolled frequency is determined by the values of resistance and capacitance in the circuit. This instrument consists essentially of a resistance-capacitance-coupled amplifier with the output connected back to the input to maintain continuous oscillation. The output waveform is highly distorted and contains hundreds of harmonics of the fundamental frequency. This type of oscillator is susceptible to control at a definite frequency if a voltage is introduced into its circuit from another oscillator, the frequency of which corresponds to the fundamental or to a low harmonic of the uncontrolled multivibrator frequency. Under this condition, the multivibrator locks into step with the frequency of the controlling source and varies only in accordance with the variations in the frequency of the controlling source.

TIME COMPARISON

The clock mechanism which is used to obtain the time comparison is driven by an impulse-type of synchronous

FIGURE 9. TYPE 676-A Quartz Bar

motor operating at a frequency of 1 kilocycle. On a shaft rotating once a second is a contact which operates once each revolution. The contact can be made to close at any instant in the one-second interval by rotating the micro-dial housing. The micro-dial carries a scale divided into one hundred parts, allowing the instant when the contact is closed to be adjusted to well within 0.01 second. In order to facilitate starting the clock when the equipment is placed in operation, a 60-cycle motor is provided by means of which the clock can be brought up to synchronous speed. The starting motor is operated by a push-button from the panel.

In comparing the time indication of the synchronous clock with radio time signals, the contact is made to short-circuit the loudspeaker of a radio receiver. The contact is of sufficient duration to eliminate the signal from the speaker. The position of this contact is adjusted until only the "nose" of the signal gets through the speaker, the remainder being entirely short-circuited. This condition is reached when (as the micro-dial is rotated in such a direction as to eliminate more of the signal) the signal ceases to be a tone and becomes a "click." This adjustment can be made with very high precision.

The precision with which the oscillator frequency is known depends directly upon the precision with which the time interval can be measured. For instance, if the time interval used is the mean solar day, and if the precision with which the time comparison can be made is 0.01 second, the average frequency of the standard oscillator is thereby determined to within one part in 8,640,000 since the mean solar day contains 86,400 seconds.

POWER SUPPLY

Either of two types of power supply units is available for use with this assembly. One of these derives the filament and plate power directly from a 115-volt, 50–60 cycle, a-c line; the other carries battery-charging equipment by means of which lead-type storage batteries, which furnish the filament and plate power, can be continuously trickle charged.

Since there is no difference in frequency stability or over-all performance with either type of power supply, the battery-charging equipment is recommended for use only where a-c line failures are frequent or where it is desired to provide against any possible failure of the timing sequence. In localities where failure of the a-c line is rare or where an occasional interruption in the timing sequence is of no importance, the simpler a-c operated assembly will be found entirely satisfactory.

The battery-charging type of power supply includes relays for transferring the temperature-control system to an auxiliary power supply if the a-c line fails.

FREQUENCY ADJUSTMENT

The frequency of the assembly, when received, may differ slightly from its true value, as a result of displacements which have taken place during shipment. The frequency can be readjusted easily to its proper value, and directions are included in the operating instructions, a complete set of which is furnished. The standard-frequency transmissions of the U. S. Bureau of Standards on 5, 10, and 15 megacycles offer a convenient standard of reference for making this adjustment.

Type 616-B Heterodyne-Frequency Meter

This unit is a combination of calibrated oscillator, detector, and audio amplifier. The oscillator has a voltage-stabilized circuit, and is temperature controlled in order to preserve the calibration.

As the oscillator-frequency is varied, audio-frequency beats with the standard-frequency harmonics or with unknown frequencies are heard. These frequencies may be separated and identified with the aid of the calibration chart of the oscillator. The fundamental or one of the harmonics of the oscillator is set to zero beat with the unknown signal by means of a local receiver, and thereafter the fundamental is used in place of the distant signal during the rest of the frequency measurement.

Type 617-B Interpolation Oscillator

A 0–5000 cycle, direct-reading, straight-line-frequency scale beat-frequency oscillator, this unit measures by a zero-beat method frequencies within its range to an accuracy of ±2 cycles. The audio-frequency beat between the unknown signal and one of the standard-frequency harmonics always falls within the range of this unit, for the standard harmonics are spaced at 10-kc intervals throughout the radio-frequency spectrum, and hence are never more than 5000 cycles from the unknown frequency or one of its sub-harmonics.

Type 619-C Heterodyne Detector

This unit, a tuned regenerative detector, combines the standard and unknown frequencies, furnishing from the combination an audio-frequency-output signal of between 0 and 5000 cycles which is then fed to the TYPE 617-B Interpolation Oscillator, above, for measurement.

Type 612-B Coupling Panel

This unit is the central control panel of the auxiliary equipment. The switches permit the interconnections necessary for a complete frequency measurement.

Type 614-A Selective Amplifier

For central installations to supply many laboratories, the selective amplifier provides exact even-kilocycle frequencies between 1 kc and 10 kc for timing, testing, and calibration purposes.

Type 480-P Blank Panels

Panels to match apparatus finish and to fill in empty rack space may be had in heights of any whole number of 1¾-inch rack units.

FIGURE 10. Interpolation and Auxiliary Equipment for use with CLASS C-21-H Standard-Frequency Assembly

INTERPOLATION AND AUXILIARY EQUIPMENT

for Use with

CLASS C-21-H STANDARD-FREQUENCY ASSEMBLY

For measuring frequencies in terms of the output frequencies from the CLASS C-21-H Standard - Frequency Assembly, the following instruments are required:

TYPE 612-B Coupling Panel

TYPE 616-B Heterodyne-Frequency Meter

TYPE 617-B Interpolation Oscillator

TYPE 619-C Heterodyne Detector

In addition, where it is desired to distribute standard harmonics of 1 kc around a laboratory, the use of a TYPE 614-A Selective Amplifier is recommended.

Figure 10 shows this equipment mounted on a relay rack and lists briefly the characteristics and the function of each instrument. Complete specifications with prices will be found on pages 39 to 46.

Using this equipment, measurements are made by the direct-beating method outlined on page 9. Frequencies from 10 kc to 30 Mc can be measured. While the same basic method is used for all frequencies, the actual manipulation depends upon the range in which measurements are made.

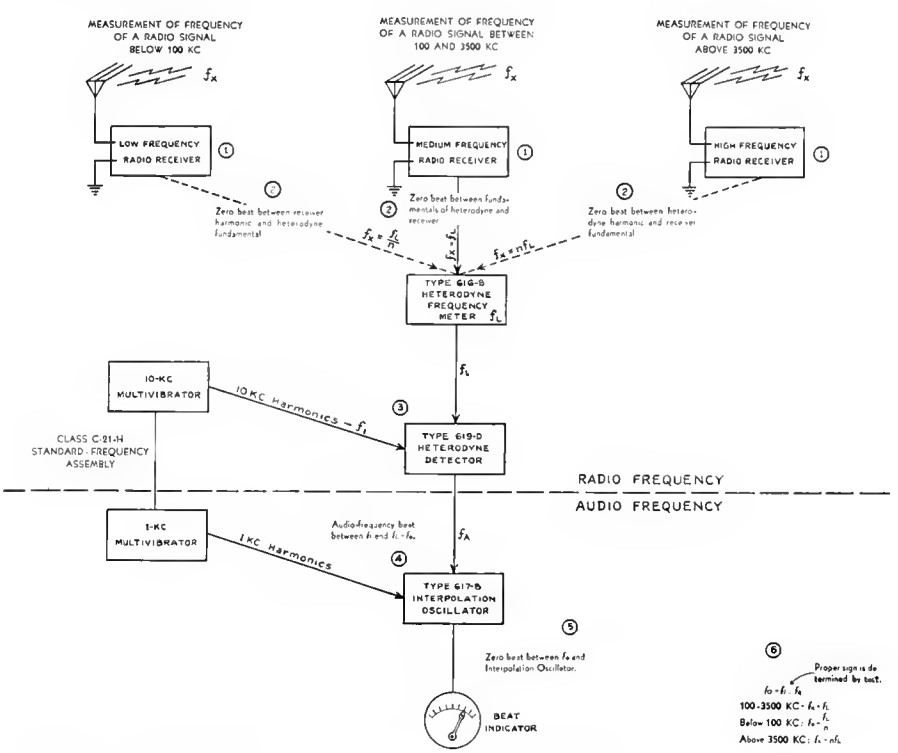


FIGURE 11. Functional diagram showing the operation of the frequency-measuring assembly

The operation of the system can best be understood by referring to the diagram of Figure 11. It will be noticed that, in the general case at least, the frequency measured is always that of the heterodyne-frequency meter, which is set to zero beat with the unknown frequency. This is necessary at frequencies above and below the medium range and is a distinct advantage in the medium range when measuring frequencies of a transient nature, since the heterodyne-frequency meter gives a strong, reliable signal, simplifying considerably the problem of measurement.

Since the harmonics from the 10-kc multivibrator in the CLASS C-21-H Standard-Frequency Assembly are strongest in the range below 3500 kc, and the low limit of fundamental frequency on the heterodyne-frequency meter is 100 kc, all measurements are made in the range between 100 kc and 4000 kc. Frequencies above 2500 kc are measured by setting an harmonic of the heterodyne-frequency meter to zero beat with the unknown frequency, and below 100 kc the heterodyne-frequency meter is set to zero beat with a harmonic of the unknown.

PROCEDURE

The procedure used should be quite clear from the diagram of Figure 11. After transferring the unknown frequency to the heterodyne-frequency meter, the frequency of the heterodyne-frequency meter is measured by beating it with the nearest 10-kc harmonic. The resultant audio-frequency beat is compared with the TYPE 617-A Interpolation Oscillator.

Simple and positive methods of determining the harmonic order n and the sign of the audio beat are used.

RECEIVERS

The diagram of Figure 11 shows three radio receivers which might be used in measuring the frequencies of signals from remote transmitters. When the frequency under measurement is not too weak, the TYPE 619-C Heterodyne Detector can be used, with the extra coils listed on page 46. Although this instrument is a simple regenerative detector, its sensitivity is of the order of one or two microvolts. For many purposes, the low-frequency range will not be required and it will be necessary to use only receivers capable of covering the two higher ranges.

FREQUENCY RANGE

This system is capable of making measurements from 10 kc to 30 Mc or higher. There is no difficulty in making measurements at 60 Mc if a good receiver covering frequencies in that vicinity is available.

ACCURACY

It will be readily seen that the overall accuracy of measurement, while very high, depends upon a number of factors. The possible error in the frequency standard is 0.5 parts in 10^6. Zero-beat settings can be made (using the so-called three-oscillator method) to well within one cycle per second, provided the frequency under measurement is sufficiently stable. The calibration of the interpolation oscillator is accurate to one cycle per second. The resultant error consequently is a maximum of one or two cycles at frequencies below a few megacycles. At high frequencies, say 30 megacycles, the error of measurement will be multiplied by the harmonic order of the heterodyne-frequency meter and will be about 10 cycles. If, however, the

frequency under measurement lies near enough to a standard-frequency harmonic to permit the beat frequency to be counted and timed, the accuracy of the measurement is within one part in 10^6.

DIRECT-READING AUDIO-FREQUENCY METER

For rapid measurements of the audio-frequency beat between the unknown and standard frequencies, the TYPE 834-A Electronic Frequency Meter is recommended. This is a direct-reading instrument which indicates on a large meter the frequency of the voltage applied to its input terminals. Specifications are given on page 38.

FIGURE 12. TYPE 834-A Electronic Frequency Meter

When a number of transmitting stations are to be measured at stated intervals as a routine monitoring procedure, the electronic frequency is a very desirable addition to the assembly because it materially reduces the time required for making the measurements.

CATHODE-RAY OSCILLOGRAPH

The cathode-ray oscillograph offers a ready means of making accurate frequency comparisons at audio frequencies. Either TYPE 687-A or TYPE 635-B Cathode-Ray Oscillograph is recommended for this purpose. These are described in Catalog H.

RACK SPACE

In adding auxiliary instruments to the assemblies as catalogued, it should be noted that 63 inches of panel space (equivalent to 36 "rack units") are available on the TYPE 480-A Relay Rack.

If it is desired to mount a number of additional instruments, the available space should be checked against the panel space required, and, if necessary, an additional rack should be ordered.

FIGURE 13. TYPE 635-B Electron Oscillograph

LINEAR-INTERPOLATION METHOD

If desired, the measurement of an unknown frequency may be made by the linear-interpolation method, using TYPE 616-B Heterodyne-Frequency Meter, although this is neither as accurate nor as rapid as the audio-beat method.

For convenience in using this method, the TYPE 616-B Heterodyne-Frequency Meter is fitted with a dial on which a movable zero mark is provided, so that the ratios

$$\frac{S_x - S_1}{S_2 - S_1} \text{ or } \frac{S_2 - S_x}{S_2 - S_1}$$

may be read directly without the necessity of taking the differences in readings on the main scale.

CLASS C-10 STANDARD-FREQUENCY ASSEMBLY

The secondary standard is adaptable for many uses where the accuracy of the primary standard is not necessary. For much of the routine frequency measurement and frequency monitoring which form necessary parts of the activities of radio communication organizations, the secondary standard is entirely satisfactory.

For use as a secondary standard, the General Radio Company provides a simplified crystal oscillator and multivibrator system designed upon the same fundamental principles as the CLASS C-21-H Standard-Frequency Assembly. The piezo-electric oscillator can be supplied to operate at either 50 kc or 100 kc. Because of its better frequency stability, the use of the 50-kc bar is recommended. The temperature control is a single-stage system which holds the temperature to well within 0.1 degree Centigrade over wide ranges of room temperature variation. A single multivibrator is provided, operating at 10 kilocycles. Harmonics of the crystal oscillator frequency can be obtained directly from the harmonic amplifier in the crystal oscillator assembly. The multivibrator is identical with those used in the primary standard. A self-contained power supply is provided, operating directly from a 115-volt, 50–60 cycle, a-c line. Sufficient excess power is available to operate a maximum of three multivibrators, if desired, or two multivibrators and a timing unit similar to that used in the primary standard. This latter arrangement is a primary standard of frequency, the frequency stability of which is not quite as good as that of the CLASS C-21-H Standard-Frequency Assembly. These assemblies are shown in diagram form in Figure 15.

FIGURE 14. CLASS C-10 Standard-Frequency Assembly

ACCURACY

The absolute accuracy of the piezo-electric oscillator is guaranteed to within 20 parts in one million (0.002%). By means of standard-frequency radio signals, however, the frequency can be adjusted to be within one part in one million. The 5-, 10-, and 15-megacycle standard-frequency transmissions of the U. S. Bureau of Standards can be used as a standard of reference against which the CLASS C-10 Standard-Frequency Assembly can be adjusted. These signals are now available on two days each week and if the assembly is checked at these intervals, its frequency will stay well within one or two parts in one million during the intervals between transmissions.

SPECIFICATIONS

Complete specifications with prices for the CLASS C-10 Standard-Frequency Assembly will be found on page 27. Prices for additional multivibrators are given on page 31. All prices include interconnecting cables for the type of assembly ordered.

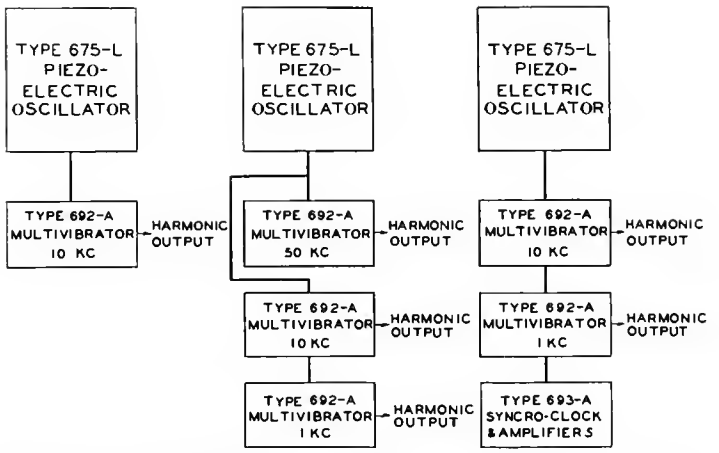


FIGURE 15. Functional diagrams of CLASS C-10 Standard-Frequency Assembly and of other possible combinations

INTERPOLATION EQUIPMENT
for Use with
CLASS C-10 STANDARD-FREQUENCY ASSEMBLY

Either the linear-interpolation or the audio-beat method of frequency measurement may be used with the CLASS C-10 Standard-Frequency Assembly. If the frequency of the crystal oscillator is checked periodically against accurate standard-frequency transmissions, the audio-beat method is recommended. Under these conditions the accuracy is nearly as good as when using a primary standard. For many purposes, however, the linear-interpolation method will be found entirely satisfactory. Relying on the original calibration of the crystal oscillator, and using the linear-interpolation method, the accuracy of measurement is 0.01% or better.

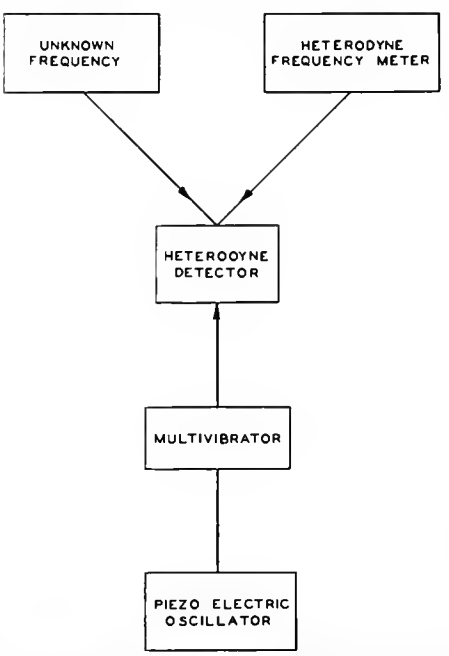


FIGURE 16. Diagram of frequency measuring system using the CLASS C-10 Standard-Frequency Assembly and the linear interpolation method of measurement

The audio-beat method requires the same auxiliary and interpolation equipment as does the primary standard (see page 15). For measurements using the linear-interpolation method, the following instruments are necessary:

TYPE 616-B Heterodyne-Frequency Meter
TYPE 619-C Heterodyne Detector

FREQUENCY MONITORING

Frequency monitoring, while employing methods and equipment as used in frequency standardization and measurement, is specialized, in that monitoring deals with the maintenance of frequencies of radio stations, rather than their measurement. The apparatus and methods, consequently, are modified to emphasize automatic or direct-reading features, or to shorten to a minimum the time required to make an observation.

FIGURE 17. TYPE 475-A Frequency Monitor

Radio broadcasting stations in the United States and many foreign countries are required by law to use frequency monitors. In order to maintain properly the frequencies of police and fire department transmitters, a monitor is practically a necessity. Many communication companies using a large number of transmitters, the frequencies of which are measured periodically at central frequency-measuring stations, have found it advisable to install monitors in the transmitting station.

General Radio frequency monitoring equipment is based upon the TYPE 475-A Frequency Monitor as a frequency standard. This instrument, which is a-c operated, consists of a temperature-controlled piezo-electric oscillator, a vacuum-tube detector, and an audio-frequency amplifier. Means are provided for introducing a voltage of the frequency to be monitored, thus producing a beat frequency corresponding to the difference in frequency between the transmitter and the monitoring standard. This beat frequency can be used to operate either a loudspeaker, giving an aural indication of frequency drift, or some type of audio-frequency meter to give a measure of the magnitude of drift.

AUDIBLE BEAT METHOD OF MONITORING

The TYPE 475-A Frequency Monitor can be used in conjunction with a loudspeaker in an audible beat method of monitoring, where the adjustment of the transmitter frequency to produce zero audible beat with the monitoring standard is sufficient assurance that the specified channel frequency tolerance is not exceeded. This method is recommended for police and fire department transmitters where tolerances

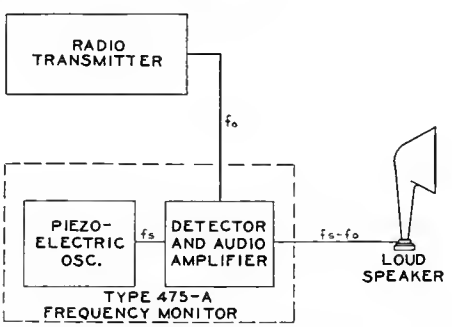


FIGURE 18. Functional diagram of the audible beat method of monitoring

of $\pm 0.04\%$ are allowed. The operation of such a monitoring system is shown diagrammatically in Figure 18. The accuracy of the system is more than adequate for present requirements and, if frequency tolerances are made more rigid in the future, a frequency-deviation meter can be added, utilizing the same monitoring standard. From the long-time viewpoint, this factor is of considerable importance.

For the international broadcasting bands and other radio-telephone service at frequencies above the normal broadcast band, this same system is recommended.

The equipment necessary for monitoring by the audible beat method is listed below:

TYPE 475-A Frequency Monitor
TYPE 376-J (or 376-K) Quartz Plate
Loudspeaker or head telephones

FREQUENCY METER

If a quantitative measure of the magnitude of the frequency drift is desired, TYPE 682-A Frequency-Deviation Meter may be used. This instrument is direct reading in frequency and will measure audio frequencies up to 5 kc. The indicator is a large pointer-type meter. Two full-scale ranges are provided, selection of which is made by a switch.

VISUAL-TYPE MONITOR FOR BROADCAST SERVICE

FIGURE 19. The General Radio visual-type frequency monitor

In the normal broadcast band, a ± 50-cycle limit of frequency deviation has been in effect since 1932. Actual operating limits are well within this figure, and most stations are holding their frequencies within ± 5 cycles. For this accuracy, a visual indicator is essential.

The General Radio TYPE 681-A Frequency-Deviation Meter is designed for this class of service. This instrument, which consists of an audio amplifier and a tuned-circuit frequency meter of unique design, indicates directly on a large, open-scale meter the difference between the transmitter frequency and that of the frequency monitor. The range of the instrument is ± 100 cycles, and a change of one cycle is readily discernible. An audible check is provided by plugging in a pair of head telephones or a loudspeaker, because, when the transmitter is exactly on frequency, the beat frequency is 1000 cycles.

The frequency meter is calibrated to read zero when a 1000-cycle voltage is applied. The quartz crystal used in the TYPE 475-A Frequency Monitor is,

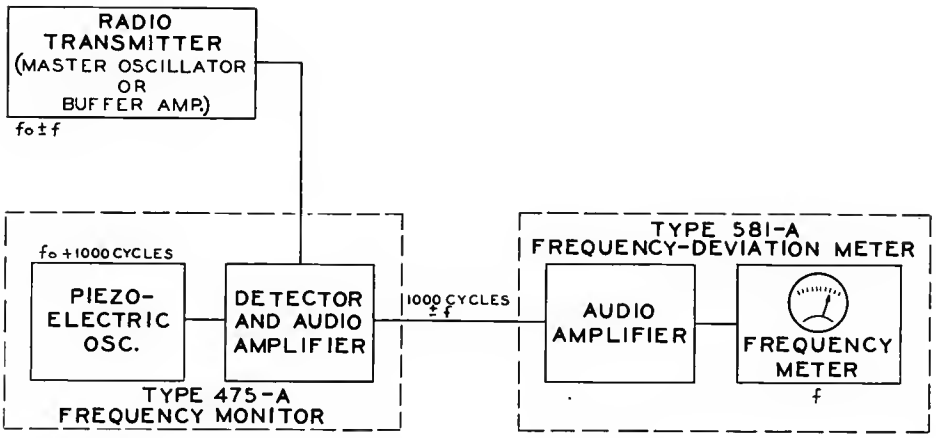


FIGURE 20. Functional diagram showing the operation of the visual-type frequency monitor

accordingly, adjusted to be either 1000 cycles above or 1000 cycles below the assigned channel frequency for the transmitter.

Since this system operates on an audible beat, the voltage from the transmitter is picked up at the master oscillator, or at one of the initial unmodulated buffer stages, in order to avoid false readings due to modulation.

The monitor consists of the following units, all of which are described in Part III. The complete monitor is listed on page 38.

TYPE 475-A Frequency Monitor

TYPE 681-A Frequency-Deviation Meter

TYPE 376-J Quartz Plate

All units are a-c operated and intended for relay-rack mounting.

ACCURACY

The guaranteed accuracy of the TYPE 475-A Frequency Monitor is $\pm 0.002\%$ (20 parts in one million). The TYPE 681-A Frequency-Deviation Meter indicates the 1000-cycle beat between the transmitter and the monitor to within ± 5 cycles. The 1000-cycle difference does not appear on the scale of the meter.

Means are provided for bringing the monitor into agreement with the measurements made by government monitoring stations. After this adjustment has been made, the drift in the monitor is entirely negligible.

ALARM SYSTEMS

Systems can be devised for operating warning signals, such as bells and flashing lamps, to meet the customer's requirements, when the frequency drift of the transmitter exceeds a predetermined value.

PART III CATALOG

WE SELL DIRECT . . .

A STATEMENT OF POLICY

The development of the type of product manufactured by the General Radio Company requires a large staff of engineers, each a specialist in one or more phases of the work involved. This staff must in a measure supply a consulting service to customers. Such a service is not of a type that is intended to solve the customer's problems, but one which will enable him to purchase the correct equipment with a minimum expenditure.

There has always been a very intimate contact between our engineers and customers. The nature of our product makes the maintenance of this contact essential. For this reason we feel that we can give better service by dealing direct rather than through manufacturers' representatives and sales agencies. We solicit your correspondence and, in turn, offer you our best service.

GENERAL RADIO COMPANY

CLASS C-21-H STANDARD-FREQUENCY ASSEMBLY

SERIES 690

This assembly is a complete primary standard of frequency supplying hundreds of standard frequencies between one cycle per second and several megacycles, each of which is known to an accuracy of better than five parts in ten million (0.00005%). Its functional arrangement and principle of operation are fully described on pages 11 to 14.

The outstanding characteristics of this equipment are high accuracy, rugged construction, and simplicity of operation.

The accuracy is conservatively specified as five parts in ten million. After being assembled and adjusted in terms of standard time, slight frequency drifts of the order of one part in a million may occur for a few weeks. After a reasonable aging period, the frequency is easily readjusted to accuracies of the order of one or two parts in ten million.

This accuracy is obtained through the use of an oscillator circuit designed to operate the quartz bar at (or very near) its resonant frequency. Both the quartz bar and the oscillator circuit elements are temperature-controlled. The constant temperature system operates over a wide range of ambient temperatures and no variation in the frequency of the oscillator can be detected when the room temperature is varied between 20° and 115° F.

The standard-frequency assembly is composed of the following instruments, each of which is described on the page indicated.

Number	*Type*	*Name*	*Page*
1	690-B	Piezo-Electric Oscillator	28
1	676-A	Quartz Bar	54
1	691-B	Temperature-Control Unit	29
3	692-A	Multivibrators	31
1	693-A	Syncro-Clock and Amplifiers	30
1	694-B	Crystal Oscillator Control Panel	29

Number	*Type*	*Name*	*Page*
1	695-A	Charging Equipment	32
		or	
1	696-A	A-C Power Supply	32
1	480-A	Relay Rack	57

Either of two types of power supply can be furnished. When the TYPE 695-A Charging Equipment is used, the assembly operates from lead-type storage batteries which are continuously trickle-charged from the a-c power line. In case of line failure the batteries will furnish filament and plate power to the assembly for several hours until line power is again available. Relays are provided for automatically switching the temperature-control system to an auxiliary power supply when the a-c line fails. This system is

recommended where line failures are frequent or where it is necessary that the timing sequence be uninterrupted.

Complete a-c operation without the use of batteries can be obtained with the TYPE 696-A Power Supply, which supplies filament and plate power directly from the a-c line. Where line failures are not frequent and occasional temporary interruptions in the timing sequence are not serious, the a-c power supply is recommended.

SPECIFICATIONS

Frequency Range: Standard frequencies between one cycle per second and several megacycles can be obtained from this assembly.

The output frequencies are as follows:

From the 50 kc multivibrator:
50 kc and its harmonics up to several megacycles. The upper limit depends upon the method used to detect and utilize them.

From the 10 kc multivibrator:
10 kc and its harmonics up to about 4000 kc. Above 4000 kc, the amplitudes of the harmonics diminish rapidly and, since their fractional separation in the frequency spectrum becomes quite small, they are not as easily identified as at lower frequencies.

From the 1 kc multivibrator:
1 kc and its harmonics in the audio-frequency range. These harmonics can be filtered and amplified for particular uses.

From the syncro-clock unit:
One-second pulses, the time of occurrence of which is adjustable over a range of one second.

Output Amplitude: The multivibrator output voltage is approximately 7 volts. Harmonic amplitudes are sufficient for heterodyne measurements over the ranges given above.

Frequency Calibration: The frequency of the quartz bar in its oscillator circuit is adjusted to within one part in ten million of its specified frequency. Slight changes in frequency may occur during shipment, and complete instructions for readjusting the frequency are furnished.

Frequency Stability: When the assembly is operated in accordance with instructions, the frequency will remain within five parts in ten million over long periods of time. Since time comparisons can be made several times daily, the frequency is known with a high degree of precision at all times.

Output Terminals: The various output frequencies are available at jack terminals on a panel at the front of the rack. This panel is permanently wired into the cable assembly. Since all necessary wiring is supplied in the form of cables, no connections need be made by the user other than power supply connections.

Vacuum Tubes: The following tubes are furnished with the instrument—

1—41-type
18—76-type
1—83-type
2—77-type

Power Supply: 115 volts, 50-60 cycles.

When the TYPE 695-A Battery Charging Equipment is used the following lead-type storage batteries are necessary:

2— 6-volt, 150 ampere-hour capacity
4—48-volt, 6000 milliampere-hour capacity

In addition, a power supply for heat reserve is recommended. This should be capable of delivering 100 watts at 115 volts.

No auxiliary power supply is necessary with the a-c operated assembly.

Power Input: Power drawn from the a-c line is approximately 225 watts.

Accessories Supplied: In addition to a complete set of tubes, spare sets of fuses and pilot lights are provided. Other accessories supplied are all connecting cables, including power supply leads, and complete operating instructions.

Mounting: All units are mounted on standard 19-inch relay-rack panels. A relay rack for mounting the units is included in the assembly.

Dimensions: The over-all dimensions are (height) 69⅛ x (width) 20 x (depth) 24 inches.

Net Weight: 370½ pounds for floating-battery assembly, 352⅜ pounds for completely a-c operated assembly, relay rack included.

Type	*Description*	*Code Word*	*Price*
Class C-21-H	**For complete a-c operation**	LAYER	**$2100.00**
Class C-21-H	**For floating-battery operation**	LYRIC	**2175.00**

Patent Notice 1, 3, 8, 9, 12, 14, 17, page 61.

INTERPOLATION AND AUXILIARY EQUIPMENT

This interpolation and auxiliary equipment used in conjunction with a CLASS C-21-H Standard-Frequency Assembly makes possible the direct precision measurement of any radio frequency up to about 25,000 kc. For frequencies above 25,000 kc measurements can be easily made by utilizing harmonics of a lower frequency oscillator.

A description of the method of measurement is given in Part II, pages14 to 17.

Where the unknown signals are to be picked up from distant transmitters, suitable receivers are required, but for measurements on local oscillators or transmitters no additional equipment is necessary.

The equipment is composed of the following individual instruments which are described on the pages indicated.

	Page
1—TYPE 616-B Heterodyne-Frequency Meter	42
1—TYPE 617-B Interpolation Oscillator	43
1—TYPE 619-C Heterodyne Detector	45
1—TYPE 612-B Coupling Panel	40
1—TYPE 614-A Selective Amplifier (Optional)	39
TYPE 480-P Blank Panels (Not Supplied Unless Ordered)	
1—TYPE 480-A Relay Rack	57

SPECIFICATIONS

Terminals: All instruments are fitted with multi-point protected plug connectors on the rear of the units. A complete interconnecting cable is furnished.

Power Supply: 110–115 volts, 50–60 cycles. Other voltages or other frequencies on special order only.

Mounting: The complete assembly mounts on a standard 19-inch, TYPE 480-A, relay rack.

Dimensions: (Height) 69⅛ x (width) 20 x (depth) 18 inches, over-all. With the TYPE 614-A Selective Amplifier the rack has 6 rack units, or 10½ inches, of empty rack space that will take other equipment. Without the TYPE 614-A Selective Amplifier the empty rack space is 11 rack units, or 19¼ inches in height.

Connections: The price of the Auxiliary and Interpolation Equipment includes a complete multi-connector cable assembly which connects all units to the coupling panel and provides for all necessary interconnections. The multi-plug connections and the assembly of the equipment on a rack permit easy accessibility from front and rear.

Net Weight: 205¼ pounds with TYPE 614-A Selective Amplifier; 167¼ pounds without TYPE 614-A Selective Amplifier.

Interpolation and Auxiliary Equipment for use with CLASS C-21-H Standard-Frequency Assembly, with TYPE 614-A Selective Amplifier	$1705.00
Blank Panel to fill rack	7.25
Total	$1712.25
Interpolation and Auxiliary Equipment, as above, without TYPE 614-A Selective Amplifier	$1430.00
Blank Panel to fill rack	13.25
Total	$1443.25

Patent Notice 1, 3, 14, 17, page 61.

CLASS C-10 STANDARD-FREQUENCY ASSEMBLY

SERIES 690

(A-C Operated)

This is an a-c operated secondary standard of frequency consisting of a piezo-electric oscillator and a single multivibrator. While its accuracy is not as great as that of the primary standard, it is more than sufficient for commercial frequency measurements or for the small laboratory.

Its absolute accuracy is ± 20 parts in one million (0.002%). Its frequency stability over long periods of time is better than five parts in one million (0.0005%). If the user checks its frequency periodically against accurate standard-frequency radio transmissions (such as the 5-10-15 megacycle transmissions of the U. S. Bureau of Standards), accuracies of the order of one or two parts in a million can be obtained.

The assembly as normally supplied consists of the following instruments, each of which is described on the page indicated.

Type	*Name*	*Page*
675-L	Piezo-Electric Oscillator	48
692-A	Multivibrator (10-kc)	31
676-A	Quartz Bar and Mounting	54
	or	
476-A	Quartz Bar with TYPE 476-P1 Mounting	53
480-B	Relay Rack	57

Additional multivibrators can be supplied for the frequencies listed on page 31.

The power supply in the piezo-electric oscillator is capable of supplying filament and plate power to a maximum of three multivibrators. It is also possible to use two multivibrators (10 kc and 1 kc) and a TYPE 693-A Syncro-Clock and Amplifier panel to determine the frequency by means of standard time.

Either a 50-kilocycle quartz bar or a 100-kilocycle unit can be supplied (see price list below). The 50-kilocycle bar is recommended because it has a better frequency stability.

SPECIFICATIONS

Frequency Range: 10 kilocycles to several megacycles. Harmonics of the crystal frequency can be obtained from the harmonic amplifier in the piezo-electric oscillator. Harmonics of 10 kilocycles are produced by the multivibrator.

Accuracy: The accuracy is ±20 parts in one million. If the frequency is readjusted by comparison with standard-frequency radio transmissions, an accuracy of better than ±5 parts in one million can be obtained.

Frequency Stability: ±5 parts in one million or better.

Output Amplitude: The multivibrator output voltage is approximately 7 volts. Harmonic amplitudes are sufficient for heterodyne measurements over the frequency ranges given above.

Power Supply: 115 volts, 60 cycles. The power supply equipment in the piezo-electric oscillator is capable of supplying power to a maximum of three TYPE 692-A Multivibrators.

Frequency Calibration: The frequency of the quartz bar in its oscillator circuit is adjusted to within one part in a million of its specified frequency. Slight changes may occur in shipment and readjustment can be made if an accurate primary standard or standard frequency radio transmissions are available. The accuracy specification of 20 parts in a million takes into account the possibility of these changes.

Tubes: The following tubes are used and are supplied with the assembly—

1—77-type
1—83-type
7—76-type

Output Terminals: The various output frequencies are available terminals on the terminal strip furnished with the interconnecting cable.

Other Accessories: All connecting cables are supplied, as are a spare set of fuses and pilot lights. No additional accessories are required.

Power Input: The power drawn from the a-c line is approximately 58 watts, heat off; 138 watts, heat on.

Dimensions: (Height) 44 x (width) 20 x (depth) 15 inches, over-all.

Net Weight: 100 pounds.

Type	*Code Word*	*Price*
Class C-10 (with 50-kc Quartz Bar)	EPOCH	**$615.00**
Class C-10 (with 100-kc Quartz Bar)	EPODE	**585.00**

Patent Notice 1, 3, 8, 9, 12, 14, 17, page 61.

TYPE 690-B PIEZO-ELECTRIC OSCILLATOR

This oscillator is designed solely for use with the TYPE 691-B Temperature-Control Unit and TYPE 676-A Quartz Bar and Mounting, and is mounted in the temperature-control box before shipment.

The circuit is designed to operate the quartz bar at or near its resonant frequency. A small condenser for adjusting the frequency over a narrow range is provided. The entire oscillator (with the exception of the quartz bar) is housed in a temperature-controlled chamber designed to be mounted at the rear of a TYPE 691-B Temperature-Control Unit.

SPECIFICATIONS

Frequency: The oscillator is normally supplied to operate at 50 kc in a CLASS C-21-H Standard-Frequency Assembly. Other frequencies between 30 kc and 100 kc can be supplied on special order.

Quartz Bar: The circuit operates only with a low frequency quartz bar and associated circuit elements such as TYPE 676-A Quartz Bar and Mounting or TYPE 476-A Quartz Bar and TYPE 476-P1 Mounting.

Vacuum Tubes: The following tubes are required and are supplied with the oscillator—

2—77-type
2—76-type

Power Supply: 6 volts, ac or dc, for cathode heaters; 180 volts dc for plate supply; 115 volts, ac or dc, for temperature control.

Mounting: The oscillator with its temperature control is mounted in a cast aluminum box arranged for mounting at the rear of a TYPE 691-B Temperature-Control Unit.

Accessories Supplied: In addition to vacuum tubes, the necessary thermostat, thermometer, and heat fuses are supplied.

Other Accessories Required: TYPE 694-B Crystal Oscillator Control Panel and TYPE 691-B Temperature-Control Unit.

Dimensions: Over-all, (length) 17¼ x (height) 10½ x (depth) 7 inches.

Net Weight: See description of TYPE 691-B Temperature-Control Unit, page 29.

Type	*Code Word*	*Price*
690-B	STANFREROD	**$185.00**

Patent Notice 1, 3, 9, 12, 14, page 61.

TYPE 691-B TEMPERATURE-CONTROL UNIT

This unit holds the temperature of the quartz bar in a CLASS C-21-H Standard-Frequency Assembly to an essentially constant value. It consists of two temperature-control systems, one inside the other. This arrangement permits a very precise control of temperature since the inside box has to work only against the variations in temperature of the outside box.

By means of distributed heaters and alternate layers of aluminum and asbestos, the slight variation in temperature which occurs at the mercury thermostats is reduced to a negligible value. The overall accuracy of the temperature of the inner chamber is within 0.01°C. over a wide range of room temperature. Tests made between −6°C. and +46°C. show no observable change in temperature.

The relays and heat-indicator lamps necessary for the operation of the heater circuits are mounted in TYPE 694-B Crystal Oscillator Control Panel.

SPECIFICATIONS

Accuracy of Temperature Control: ±0.01°C. between −6°C. and +46°C.

Controls: Thermostats and thermometers are mounted in the instrument. Heat indicator lamps and relays are mounted in TYPE 694-B Crystal Oscillator Control Panel.

Accessories Supplied: Mercury thermostats and thermometers; heat fuses with spares.

Other Accessories Required: TYPE 694-B Crystal Oscillator Control Panel.

Normal Operating Temperatures: Outer compartment, 50°C.; inner compartment, 55°C.

Power Supply: 115-volt, a-c or d-c line.

Mounting: The unit is mounted on a standard 19-inch relay-rack panel, finished in black crackle lacquer. The temperature-control system is completely enclosed in sheet brass, nickel plated.

Dimensions: Panel, (length) 19 x (height) 15¾ inches; behind panel, (length) 17¼ x (height) 15¼ x (depth) 23½ inches.

Net Weight: (Including TYPE 690-B Piezo-Electric Oscillator) 104 pounds.

Type	*Code Word*	*Price*
691-B	STANFREPIG	**$560.00**

Patent Notice 8, page 61.

TYPE 694-B CRYSTAL OSCILLATOR CONTROL PANEL

On the TYPE 694-B Crystal Oscillator Control Panel are mounted the necessary meters, relays, and controls for operating both the piezo-electric oscillator and the temperature-control system in the CLASS C-21-H Standard-Frequency Assembly. In addition to the necessary ON-OFF switches, three heat indicator lamps are provided which light when the heater current is on and are extinguished when it is off. This provides a visual check on the operation of the temperature-control system.

An oscillator plate current meter and a diode current meter which gives a measure of oscillator amplitude are also included.

Since neither the TYPE 690-B Piezo-Electric Oscillator nor the TYPE 691-B Temperature-Control Unit can be operated without the control panel, this panel should be ordered with them.

SPECIFICATIONS

Mounting: Standard 19-inch relay-rack panel, with dust cover.

Dimensions: Panel, (length) 19 x (height) 5¼ inches; behind panel, (length) 17⅜ x (height) 5 x (depth) 10¾ inches.

Net Weight: 15 pounds.

Type	*Code Word*	*Price*
694-B	STANFRETOP	**$150.00**

TYPE 693-A SYNCRO-CLOCK AND AMPLIFIERS

This instrument is the timing unit used in the CLASS C-21-H Standard-Frequency Assembly. It consists of an input amplifier, a TYPE 611 Syncro-Clock (see page 56), and an output amplifier. The clock is so geared that when the frequency of the driving voltage is 1 kc, the clock keeps true time. The reading of the clock is compared with standard time pulses, such as radio time signals, by means of an adjustable contact on the one-second shaft of the clock. This contact can be adjusted until it operates at the same instant that the time signals are received. The mean frequency of the system is then determined by the clock reading as compared with standard time.

Comparisons can be made to better than 0.01 second. This one-second contact can also be used for chronographic work.

The syncro-clock is provided with a small starting motor which operates from a 115-volt, 60-cycle, a-c line.

The output amplifier is intended for delivering a standard 1-kilocycle voltage for frequency measurement or other laboratory purposes.

SPECIFICATIONS

Frequency: One kilocycle.

Accuracy: When the driving frequency is exactly one kilocycle, the clock keeps mean solar time.

Vacuum Tubes: One 41-type tube and one 76-type tube are required and are supplied with the instrument.

Power Supply: The cathode heaters must be operated from a 6-volt, d-c or a-c source. A plate supply of 180 volts is required.

One-Kilocycle Input: 8 volts at 1 kc are necessary to operate the instrument.

Meters: Plate milliammeter.

Controls: ON-OFF switch; grid-bias control; input level control.

Mounting: Standard 19-inch relay-rack panel. A metal dust cover is provided. Access to the clock is obtained through a door in the panel.

Dimensions: Panel, (length) 19 x (height) 7 inches; behind panel, (length) 17⅜ x (height) 6¾ x (depth) 10¾ inches.

Net Weight: 35 pounds.

Type	*Code Word*	*Price*
693-A	STANFREBUG	**$400.00**

Patent Notice 1, page 61.

TYPE 692-A MULTIVIBRATOR

These instruments are designed for use as frequency dividers in General Radio standard-frequency assemblies, but are also available for general laboratory and experimental use. A description of the function of the multivibrator is given on page 7.

All models have identical circuit arrangements, differing only in values of circuit constants as chosen to facilitate operation in the vicinity of the rated fundamental frequency. Each unit consists of a control input adjustment, an input amplifier, a multivibrator using two vacuum tubes, and two output amplifiers. One output amplifier is intended for use in controlling the frequency of other multivibrators, the other for supplying harmonics of the multivibrator fundamental frequency.

The uncontrolled frequency is adjustable over a narrow range by means of a condenser accessible from the panel.

The entire unit is small and compact, mounted on a 19-inch relay-rack panel, $5\frac{1}{4}$ inches high. Vacuum tubes are of the 6-volt separate-heater type. The electrical design is such that permanent and positive control is obtained over indefinite periods of time.

SPECIFICATIONS

Frequency: Standard models are available for operation at three fundamental frequencies (see price list below), but multivibrators for operation at other frequencies can be supplied on special order.

Vacuum Tubes: Five 76-type tubes are supplied with the instrument.

Power Supply: A source of 6 volts, ac or dc, is required for the cathode heaters, 135 to 180 volts dc for plate supply.

Terminals: All external connections are made by means of multipoint, plug-type connectors, completely enclosed.

Mounting: The instrument is mounted on a standard 19-inch relay-rack panel. A dust cover is included.

Dimensions: Panel, (length) 19 x (height) $5\frac{1}{4}$ inches; behind panel, (length) $17\frac{3}{8}$ x (height) 5 x (depth) $10\frac{3}{4}$ inches.

Net Weight: 16 pounds.

Type		*Code Word*	*Price*
692-A	**1 kc**	STANFREANT	**$140.00**
692-A	**10 kc**	STANFREBOY	**140.00**
692-A	**50 kc**	STANFRECAT	**140.00**

Patent Notice 1, page 61.

TYPE 695-A CHARGING EQUIPMENT

When the CLASS C-21-H Standard-Frequency Assembly is operated from floating batteries, the TYPE 695-A Charging Equipment is used. This panel carries the necessary transformers, rectifiers, and filters for continuously trickle-charging filament- and plate-supply storage batteries. Power is derived from the a-c line.

The plate-battery charging system uses a thermionic rectifier; the filament-battery charger a copper-oxide unit.

Relays are included for transferring the heater circuits of the temperature-control system to an auxiliary power supply when the a-c line fails. Terminals for connecting the auxiliary power supply are provided.

SPECIFICATIONS

Load Capacity: The voltage and current ratings for the high- and low-voltage circuits, respectively, are:

Voltage	*Current*
180–200 volts	100 ma
6 volts	10 a

Vacuum Tubes: One 83-type rectifier tube is required and is supplied with the instrument.

Other Accessories Supplied: Pilot lights and fuses with spares.

Power Supply: 110–115 volt, 50–60 cycle, a-c line.

Power Input: At full load the power drawn from the a-c line is 225 watts.

Controls: ON-OFF switches, plate-charging-current control, Variac for filament charging-current control.

Meters: Voltmeters and charging- and load-current meters for both high- and low-voltage circuits.

Mounting: Standard 19-inch relay-rack panel.

Dimensions: Panel, (length) 19 x (height) 10¾ inches; behind panel, (length) 17¼ x (height) 10½ x (depth) 13 inches.

Net Weight: 68 pounds.

Type	*Code Word*	*Price*
695-A	STANFREDOG	**$275.00**

TYPE 696-A POWER SUPPLY

This panel is used when the CLASS C-21-H Standard-Frequency Assembly is operated directly from the a-c line. It includes a low-voltage transformer with five 6-volt filament secondaries and a high-voltage secondary with thermionic rectifier and filter for supplying 180 volts dc.

SPECIFICATIONS

Load Capacity: Voltage and current ratings for the high- and low-voltage circuits, respectively, are:

Voltage	*Current*
180 volts	100 ma
6 volts	10 a (each of five circuits)

Vacuum Tubes: One 83-type tube is supplied.

Other Accessories Supplied: Pilot lights and fuses, with spares.

Power Supply: 110–115 volt, 50–60 cycle, a-c line.

Power Input: At full load the power drawn from the a-c line is 225 watts.

Controls: On-off switch, Variac for adjusting line voltage.

Meters: Filament voltmeter, plate voltmeter, and milliammeter.

Mounting: Standard 19-inch relay-rack panel.

Dimensions: Panel, (length) 19 x (height) 7 inches; behind panel, (length) 17⅜ x (height) 6¾ x (depth) 10¾ inches.

Net Weight: 50 pounds.

Type	*Code Word*	*Price*
696-A	STANFRERUG	**$200.00**

REPLACEMENT THERMOSTATS AND THERMOMETERS

Replacement mercury thermostats and thermometers are available at the following prices:

Type	*Description*	*Operating Temperature*	*Used in Type*	*Price*
691-P1	Fixed Mercury Thermostat	50° C.	691-B (Outer), 475-A, 575-E (Serial Nos. 301 and above), 675-H, 675-L, 747-A	**$22.00**
691-P2	Fixed Mercury Thermostat	55° C.	691-B (Inner), 690-B (Circuit)	**22.00**
547-P2	Adjustable Mercury Thermostat		575-E (Serial Nos. 11 through 300) using adjustable thermostats	**20.00**
690-P1	Thermometer	*Range* 50–70°C. 0.5° divisions	690-B (Circuit)	**4.00**
691-P3	Thermometer	54–56°C. 0.1° divisions	691-B (Inner)	**4.00**
747-P1	Thermometer	40–60°C. 0.5° divisions	475-A, 575-E, 675-H, 675-L, 747-A 691-B (Outer)	**4.00**

TYPE 475-A FREQUENCY MONITOR
(A-C Operated)

The TYPE 475-A Frequency Monitor is a piezo-electric oscillator with built-in detector and amplifier designed for monitoring the frequencies of radio transmitters at frequencies above 100 kc. The fundamental frequency range is 100 kc to 4000 kc. Transmitters operating above 4000 kc can be monitored by using harmonics of the fundamental. Monitoring is accomplished by using the difference frequency between the piezo-electric oscillator and the transmitter as an indication of the frequency deviation.

For stations operating above the usual broadcast frequency band, as, for instance, police transmitters, an audible beat method of monitoring is satisfactory. If a definite measurement of the beat frequency is desired, a TYPE 434-B Audio-Frequency Meter or a TYPE 682-A Frequency-Deviation Meter may be used. For the standard broadcast band, a TYPE 681-A Frequency-Deviation Meter is necessary (see page 36). A further discussion of the uses of this frequency monitor will be found on page 20.

The TYPE 475-A Frequency Monitor is completely a-c operated and designed for relay-rack mounting. All vacuum tubes are supplied. The internal power supply will provide filament and plate power for operating additional units, such as frequency-deviation indicators.

SPECIFICATIONS

Frequency Range: 100 kc to 4000 kc (fundamental), using TYPE 376-J and TYPE 376-K Quartz Plates. Frequencies up to 60 Mc can be monitored against harmonics of the crystal oscillator if the audible beat method of monitoring is used.

Accuracy: The accuracy is the same as that stated for the TYPE 675-H Piezo-Electric Oscillator (page 47).

Quartz Plate: Not furnished with instrument which is intended for use only with the TYPE 376-J and TYPE 376-K Quartz Plate (page 52).

Temperature Control: The temperature-control system is identical with that used in the TYPE 747-A Temperature-Control Box (see page 54).

Accuracy of Temperature Control: The unit will control the temperature of the inner space to within ±0.1°C. for room temperature changes of ±16°C. (±29°F.).

Operating Temperature: Normally 50°C., but thermostats for other temperatures can be supplied on special order.

Thermostat: Fixed, or non-adjustable, mercury type. Accuracy of working point ±0.2°C. Sensitivity 0.05°C.

Crystal Oscillator: The circuit is designed to operate the quartz plate very close to its fundamental frequency. A distinct advantage from the standpoint of operation lies in the method of tuning. The proper operating point is indicated by a minimum in the oscillator plate current.

Inductor: One TYPE 575-DP Inductor (page 51) is furnished with one quartz plate. If two quartz plates are used, and the second is outside the frequency range of the coil used with the first, an additional coil, at extra cost, is required.

Detector and Amplifier: The detector and amplifier are resistance coupled to give satisfactory performance at low beat frequencies. The output transformer may be used to operate telephone receivers or, by interchanging the windings, to operate a 4000-ohm magnetic loudspeaker.

Output: The audio frequency output depends upon the beat frequency and upon the coupling employed between the monitor and the transmitter. With very moderate coupling an output of 40 volts at 500 cycles may be obtained across 20,000 ohms (telephones), beating at crystal fundamental frequency.

Power Supply: 105–125 volts, 50–60 cycles. Other voltages or other frequencies on special order only. Provision is made through a multipoint, protected, plug-type connector for obtaining power supply (3 filament circuits at 6 volts and plate supply at 180 volts) for external devices such as amplifiers or deviation indicators.

Power Input: 45 watts with heat off; 125 watts with heat on.

Controls: Power supply ON-OFF switch; heat ON-OFF switch; line input voltage control; crystal selector switch; crystal oscillator tuning condensers, fine and coarse tuning.

Meters: Filament and plate voltage; crystal oscillator plate current.

Tubes: Furnished with the instrument.
1—77-type crystal oscillator
1—76-type detector
1—76-type audio amplifier
1—5Z3-type rectifier

Mounting: Standard 19-inch relay-rack mounting.

Accessories Supplied with Instrument:
Vacuum tubes
Thermostat
Thermometer
Pilot light, Fuses, Fusible link } with spares
110-volt attachment cord
1—TYPE 575-DP Inductor
2 Multipoint connectors

Additional Accessories Required:
TYPE 376 Quartz Plate

Dimensions: Panel, (length) 19 x (height) 17½ inches; behind panel, (length) 17¼ x (height) 17¼ x (depth) 10¾ inches.

Net Weight: 68 pounds.

Type		*Code Word*	*Price*
475-A	.....	MOGUL	**$330.00**

Patent Notice 1, 3, 8, 9, 12, 17, page 61.

VISUAL-TYPE FREQUENCY MONITOR (A-C Operated)

The visual-type frequency monitor is designed for use in radio broadcasting stations where the specified frequency tolerance is ± 50 cycles. The monitor consists of the following instruments, each of which is described on the page indicated.

A description of the principle of operation is given on pages 21 to 22.

The features of this monitor are high accuracy, long-time stability, a-c operation, and relay-rack mounting. It has been approved by the Federal Radio Commission and assigned Approval No. 1452. General Radio visual-type monitors are used by over two hundred broadcasting stations.

SPECIFICATIONS

Frequency Range: ±100 cycles.

Accuracy: When received, ±25 parts in one million; an adjustment is provided to bring the reading into agreement with monitoring station measurements.

Vacuum Tubes: The following tubes are required and are supplied with the instrument—

1—77-type
4—76-type
1—41-type
1—83-type

Stability: ±5 parts in one million.

Other Accessories Supplied: Connecting cables, pilot lights, and fuses (with spares).

Power Supply: 110–115 volt, 50–60 cycle, a-c line.

Power Input: 155 (heat on) watts.

Mounting: Standard 19-inch relay-rack panels.

Dimensions: Panel, (length) 19 x (height) 22¾ inches; behind panel, (length) 17¼ x (height) 22½ x (depth) 11¾ inches.

Net Weight: 95 pounds.

	Code Word	*Price*
Visual-type Frequency Monitor	DEVOR	**$560.00**

Patent Notice 1, 3, 7, 8, 9, 12, 17, page 61.

TYPE 681-A FREQUENCY-DEVIATION METER

The TYPE 681-A Frequency Deviation Meter is designed for use in conjunction with the TYPE 475-A Frequency Monitor as a visual-type frequency monitor for radio broadcasting stations. The meter scale is of the zero-center type and is graduated in 10-cycle steps from −100 cycles to +100 cycles. A change of one cycle is readily discernible. Since, in this system, the standard of reference differs from the transmitter channel frequency by 1000 cycles, zero on the meter scale corresponds to an audio-frequency input of 1000 cycles.

In addition to the frequency meter, the assembly contains an audio amplifier to raise the level of the audio-frequency signal from the TYPE 475-A Frequency Monitor to that required to operate the frequency meter. Power supply is derived from the TYPE 475-A Frequency Monitor. The TYPE 681-A Frequency-Deviation Meter is designed for mounting on a standard 19-inch relay rack.

SPECIFICATIONS

Accuracy: ±5 cycles for frequency deviations below 50 cycles.

Frequency Range: −100 cycles to +100 cycles (transmitter frequency deviation).

Power Supply: Derived from TYPE 475-A Frequency Monitor.

Controls: Input level control; scale correction adjustment; ON-OFF switch.

Meters: Frequency-deviation indicator; amplifier output voltage.

Tubes: Furnished with the instrument.
2—76-type
1—41-type

Mounting: 19-inch relay-rack panel.

Accessories Supplied with Instrument:
Vacuum tubes
Spare pilot lights } with spares
Spare fuses }
Interconnecting cable (when sold with TYPE 475-A Frequency Monitor)

Dimensions: Panel, (length) 19 x (height) 7 inches; behind panel, (length) 17¼ x (height) 6¾ x (depth) 11¾ inches.

Net Weight: 26 pounds.

Type	*Code Word*	*Price*
681-A	MASON	**$145.00**

Patent Notice 1, 7, page 61.

TYPE 682-A FREQUENCY-DEVIATION METER

This instrument is a direct-reading visual-type frequency meter. It is similar in appearance and in operation to the TYPE 834-A Electronic Frequency Meter (see page 38). It differs from that instrument in that no power supply is included, and fewer ranges are provided.

The TYPE 682-A Frequency-Deviation Meter is intended for use in conjunction with the TYPE 475-A Frequency Monitor in monitoring radio transmitters at frequencies above the normal broadcast band. Power supply is obtained from the monitor, or, if desired, any suitable external power supply may be used. Two frequency scales are provided, with full-scale ranges of 1000 cycles and 5000 cycles respectively.

SPECIFICATIONS

Frequency Range: 0–5000 cycles in two ranges. Full-scale values are 1000 and 5000 cycles.

Accuracy: 2% of full-scale reading or better.

Stability: With the exception of a drift of about 1% of full-scale reading in the first few minutes after starting, there is no material change in indication with time.

Input Impedance: Approximately 20,000 ohms.

Input Voltage: 2 volts, minimum; the input voltage may be increased to 200 volts with no change in the frequency indication.

Scale Adjustment: Independent adjustment is provided on each range. This adjustment is made at the factory, but may be changed if correction is required in the field.

Power Supply: Usually obtained from TYPE 475-A Frequency Monitor. The plate supply is 180 volts dc; filaments, 6 volts ac.

Controls: ON-OFF switch; plate voltage adjustment; deionizer switch; range selector.

Meters: Plate voltage; frequency.

Tubes: Supplied with instrument.
2—885 gas-discharge tubes
1—874 regulator
1— 84 diode switching

Mounting: Standard 19-inch relay-rack panel, with dust cover.

Accessories Supplied: Vacuum tubes, fuses and pilot lights (with spares), multipoint connector.

Dimensions: Panel, (width) 19 x (height) 8¾ x (depth) 12 inches.

Net Weight: 24 pounds.

Type		*Code Word*	*Price*
682-A	.....	MISTY	**$145.00**

Patent Notice 9, page 61.

TYPE 834-A ELECTRONIC FREQUENCY METER
(A-C Operated)

The TYPE 834-A Electronic Frequency Meter fills the need for a general-purpose audio-frequency meter with a pointer-type, direct-reading indication. The frequency is indicated on a large panel-type meter. Five full-scale ranges are provided, covering a range of from 0 to 5000 cycles. The range selection is made by means of a switch. The accuracy of indication is 2 per cent of full scale or better.

The instrument consists essentially of an electronic counter and an indicator. When an alternating voltage is applied to the grids of the gas-discharge tubes, each tube becomes alternately conducting and non-conducting. At each transition of the current from one tube to the other, a current pulse is sent through the indicator circuit. The meter reading depends upon the number of pulses per second, i.e., upon the frequency.

The TYPE 834-A Electronic Frequency Meter is designed for a-c operation and relay-rack mounting.

SPECIFICATIONS

Frequency Range: 0–5000 cycles in five ranges. Full-scale values are 200, 500, 1000, 2000, and 5000 cycles.

Accuracy: 2% of full-scale reading or better.

Stability: With the exception of a drift of about 1% of full-scale reading in the first few minutes after starting, there is no material change in indication with time.

Input Impedance: 1 megohm, approximately.

Input Voltage: 2 volts, minimum; the input voltage may be increased to 200 volts with no change in the frequency indication.

Scale Adjustment: Independent adjustment is provided on each range. This adjustment is made at the factory, but may be changed if correction is required in the field.

Power Supply: 115 volts, 50–60 cycles.

Power Input: 45 watts.

Controls: Power supply ON-OFF switch; plate voltage adjustment; deionizer switch; multiplier (range selector) switch.

Meters: Plate voltage; frequency.

Tubes: Supplied with instrument.

1—76 amplifier
2—885 gas-discharge tubes
1—874 regulator
1—82 rectifier
1—84 diode switching

Mounting: Standard 19-inch relay-rack mounting. Unit fitted with dust cover.

Accessories Supplied with Instrument: Vacuum tubes, fuses and pilot lamps (with spares), 115-volt cord-and-plug assembly, multipoint connector.

Additional Accessories Required: None.

Dimensions: Panel, (width) 19 x (height) 8¾ x (depth) 12 inches.

Net Weight: 37 pounds.

Type	*Code Word*	*Price*
834-A	MUCUS	**$250.00**

Patent Notice 1, 9, page 61.

TYPE 614-A SELECTIVE AMPLIFIER

This amplifier is intended for use with the CLASS C-21-H Standard-Frequency Assembly to produce, select, and amplify multiples of the 1-kc output in the audio-frequency range. It is extremely useful where it is desired to distribute standard audio frequencies in a laboratory, and it also provides harmonics for checking the calibration of a TYPE 617-A Interpolation Oscillator.

Selection of the output frequency is made by a ten-point switch. The first 10 harmonics of the 1-kc input are available at the output terminals. Regeneration is used to increase the selectivity.

The amplifier is a-c operated and designed for relay-rack mounting.

SPECIFICATIONS

Frequency Range: 1 kc to 10 kc inclusive, in steps of 1 kc.

Calibration: Adjusted at factory for response at each multiple of 1 kc. Trimming adjustments are provided, for use in realignment, if necessary.

Tubes: The following vacuum tubes are required and are supplied with the instrument—

3—56-type
1—82-type

Power Supply: 115 volts, 50–60 cycles. The power drawn from the line is 25 watts.

Mounting: Standard 19-inch relay-rack panel, finished in black crackle lacquer.

Dimensions: Panel, (length) 19 x (height) 8¾ inches; behind panel, (length) 17¼ x (height) 8½ x (depth) 8¾ inches.

Net Weight: 38 pounds.

Type	*Code Word*	*Price*
614-A	DICKY	**$275.00**

Patent Notice 1, page 61.

TYPE 612-B COUPLING PANEL

This panel is designed for use in the frequency measuring system described on pages 14 to 17. It carries the necessary volume controls and switches for transferring frequencies from one unit to another and for mixing frequencies to obtain audio-frequency beats in the heterodyne detector. The use of the TYPE 612-A Coupling Panel considerably simplifies the process of measuring frequencies, since all operations can be performed at a single operating position.

SPECIFICATIONS

Terminals: Connections to the various instruments comprising the frequency-measuring equipment (page 14) are made through multipoint protected plug-type connectors at the rear of the instrument. Telephone and speaker jacks and terminals also appear on the panel. Connections for introducing a voltage of the unknown frequency also appear on the panel.

Mounting: Standard 19-inch relay-rack mounting.

Accessories Supplied with Instrument:
2—274-M plugs
3 Multipoint connectors

Additional Accessories Required:
Telephones or a speaker

Dimensions: Panel, (length) 19 x (height) 7 inches; behind panel, (length) 17¼ x (height) 6¾ x (depth) 3¾ inches.

Net Weight: 6¼ pounds.

Type	*Code Word*	*Price*
612-B	MARRY	**$65.00**

TYPE 615-A HETERODYNE-FREQUENCY METER

The TYPE 615-A Heterodyne-Frequency Meter is a portable oscillating frequency meter of high stability. The portable feature is of considerable advantage, since the instrument can be calibrated in the laboratory and then taken to points remote from the laboratory for making frequency measurements. A detector is included for listening to heterodyne beats. A thermometer is mounted on the panel to indicate the temperature inside the instrument, which allows the calibration to be corrected for difference between calibration and operating temperatures.

The oscillator uses a modified Colpitts circuit which is stabilized to reduce frequency variations due to supply voltage changes.

The condenser is of the worm-drive precision type with plates shaped to give a linear variation in frequency with scale reading. The ratio of maximum to minimum frequency for any coil position is 1.4 to 1, and the effective range is 1.3 to 1.

The inductance system consists of three tapped coils providing eleven ranges, selection of which is made by a switch.

SPECIFICATIONS

Frequency Range: The fundamental frequency is adjustable from 275 kc to 5000 kc. In frequency measurement, the use of harmonic methods extends the useful range to about 30 megacycles.

Calibration: A list of calibrated points is supplied. Ten or more points are calibrated at each of the eleven settings of the coil selector. Since the condenser scale is linear in frequency, calibration curves can be easily drawn if desired.

Accuracy: It is recommended that the calibration be checked frequently. The original calibration can be relied upon to 0.1% for a considerable period of time, provided a correction is made for the difference between calibrating and operating temperatures.

Output: Two coupling systems are provided, one capacitively coupled to the oscillator anode and the other a radio-frequency transformer in the detector plate circuit. The first system is ordinarily used when listening in the heterodyne unit itself. Fundamental and harmonic output for use with external apparatus is obtained from the second arrangement.

Power Supply: Power is furnished by self-contained batteries, namely, two 6-inch dry cells for the filaments and two 45-volt vertical B batteries (Burgess No. 5308) for the plates. Space for batteries is provided in the cabinet.

Controls: ON-OFF switch; coil selector; variable condenser; compensating condenser adjustment; filament potentiometer.

Terminals: Coupling terminals and telephone terminals (for listening to beats) are mounted on the panel.

Meters: Filament voltage; plate voltage; detector plate current.

Tubes: Furnished with the instrument.

1—32-type oscillator
1—30-type detector

Mounting: The instrument is mounted on an aluminum panel and is enclosed in an aluminum cabinet with cover and carrying handle.

Accessories Supplied with Instrument:

1—274-M plug
1 Battery cable (for external batteries)
Vacuum tubes

Additional Accessories Required:

Telephones
Batteries

Dimensions: (Length) 20 x (depth) 8 x (height) 13½ inches, over-all.

Net Weight: 34½ pounds without batteries; 45½ pounds with batteries.

Type	*Code Word*	*Price*
615-A	MANLY	**$375.00**

Patent Notice 1, 3, page 61.

TYPE 616-B HETERODYNE-FREQUENCY METER
(A-C Operated)

The TYPE 616-B Heterodyne-Frequency Meter is used either as a calibrated frequency-measuring device or as an interpolation oscillator in conjunction with standard-frequency equipment. It consists of a highly stable radio-frequency oscillator, a detector and audio amplifier for listening to heterodyne beats, and a harmonic output transformer.

The condenser has an auxiliary dial by means of which zero-beat settings may be made accurately at the low radio frequencies where the zero audible beat zone is several divisions wide. This dial is also very convenient in making interpolations on the scale of the instrument, since scale intervals are indicated directly without the necessity of subtracting two readings.

Its performance characteristics are similar to those of the TYPE 615-A Heterodyne-Frequency Meter (page 40). A straight-line-frequency precision condenser is used as a frequency control. It differs from the portable instrument in that it is of more rugged construction, covers a wider fundamental frequency range, is alternating-current operated, and is designed for relay-rack mounting.

Experience with the TYPE 616-A Heterodyne-Frequency Meter, which this instrument replaces, indicated that variations of frequency with changes in room temperature were sufficient to be troublesome when using the frequency meter in high frequency measurements against a primary frequency standard. In the TYPE 616-B Heterodyne-Frequency Meter, temperature control of the oscillating circuit is provided to overcome this objection. The construction of the precision variable condenser has also been substantially modified through the use of a cast frame, heavy plates, and ball-bearings.

SPECIFICATIONS

Frequency Range: The fundamental frequency is adjustable from 100 kc to 5000 kc. In frequency measurement, the use of harmonic methods extends the useful range to about 30 megacycles.

Calibration: A list of calibrated points is supplied. Ten or more points are calibrated at each setting of the coil selector. Since the condenser scale is linear in frequency, calibration curves can easily be drawn if desired.

Accuracy: It is recommended that the calibration be checked frequently. The original calibration can be relied upon to 0.1%.

Output: Two coupling systems are provided, one capacitively coupled to the plate of the oscillator tube and the other a radio-frequency transformer in the detector plate circuit. The first system is ordinarily used when listening in the heterodyne unit itself. Fundamental and harmonic output for use with external apparatus is obtained from the second arrangement.

Power Supply: 105–125 volts, 50–60 cycles. Other voltages or other frequencies on special order only.

Power Input: 30 watts.

Controls: ON-OFF switch; coil selector; variable condenser, main and auxiliary; compensating condenser adjustment; heat ON-OFF switch; input voltage control; hum control.

Terminals: The output coupling terminals and telephone terminals are brought out on both the panel and the rear of the unit. The terminals at the rear are brought out through multipoint, protected, plug-type connectors.

Meters: Line input voltage; oscillator plate current.

Tubes: Furnished with the instrument.

1—57-type oscillator
2—56-type detector-amplifiers
1—82-type rectifier

Mounting: Standard 19-inch relay-rack mounting. Can be supplied in walnut cabinet on special order.

Accessories Supplied with Instrument:

Vacuum tubes
Thermostat
1—274-M plug
Pilot light, Fuses, Fuse link } with spares
Multipoint connector

Dimensions: Panel, (length) 19 x (height) 14 inches; behind panel, (length) 17¼ x (height) 13⅝ x (depth) 10¾ inches.

Net Weight: 63 pounds.

Type		*Code Word*	*Price*
616-B	.....	MANOR	**$575.00**

Patent Notice 1, 3, 14, page 61.

TYPE 617-B INTERPOLATION OSCILLATOR
(A-C Operated)

A rapid and accurate means of measuring the difference between a radio frequency under measurement and a standard 10-kilocycle harmonic is indispensable in precise frequency measurement work. The TYPE 617-B Interpolation Oscillator has been designed specifically for this purpose. The oscillator is of the beat-frequency

type. The radio-frequency oscillators are similar to those used in the TYPES 615-A and 616-B Heterodyne-Frequency Meters (pages 40 and 42).

The condenser controlling the frequency of the variable oscillator is of the precision worm-drive type. The plates are shaped to give a linear variation in frequency with dial reading. The scale is direct reading, one cycle per scale division.

This oscillator is primarily intended to be used with a CLASS C-21-H Standard-Frequency Assembly (page 24), from which calibrating frequencies may be obtained for checking at a number of points of the range. This provides a rapid and convenient means for measuring differences between radio frequencies with an accuracy of one cycle. Means for introducing a standard calibrating frequency or an unknown frequency to be measured are provided. Beats between the oscillator and standard frequencies may be observed on a visual beat indicator. This allows the calibration to be checked whenever used. Means are also provided for using the indicator to compare the unknown and standard frequencies directly without using the interpolation oscillator. Where an audio-frequency standard is not available, the zero-beat setting or a setting against the 60-cycle alternating-current line voltage may be used to adjust the scale.

SPECIFICATIONS

Frequency Range: 0–5000 cycles per second.

Accuracy: The scale is direct reading in frequency to better than ±5 cycles per second. A correction curve is furnished which enables an accuracy of ±1 cycle per second to be obtained.

Output: The output voltage is approximately 3 volts.

Power Supply: 105–125 volts, 50–60 cycles. Other voltages or other frequencies can be supplied on special order.

Power Input: 30 watts.

Controls: ON-OFF switch; standard input control; checking switch; 1-kc harmonic, detector output switch; oscillator volume control; output voltage meter shunt; zero adjustment condenser.

Terminals: Terminals, both on the panel and at the rear, are provided for telephones and for introducing the standard calibrating voltage or the unknown frequency voltage. There are additional terminals on the rear for introducing a standard 1-kc frequency and its harmonics. The terminals at the rear are brought out through multipoint protected plug-type connectors.

Meters: Detector plate current; output voltage.

Tubes: Furnished with the instrument.

2—57-type oscillators
2—56-type detector-amplifiers
1—82-type rectifier

Accessories Supplied with Instrument:

2—274-M plugs
Pilot light, Fuses } with spares
110-volt attachment cord
1 Multipoint connector

Mounting: Standard 19-inch relay-rack mounting. Can be supplied in walnut cabinet on special order.

Additional Accessories Required:

Telephones

Dimensions: Panel, (length) 19 x (height) 14 inches; behind panel, (length) 17¼ x (height) 13⅝ x (depth) 10¾ inches.

Net Weight: 63 pounds.

Type	*Code Word*	*Price*
617-B	MAPLE	**$500.00**

Patent Notice 1, 3, 14, 17, page 61.

TYPE 619 HETERODYNE DETECTOR

This instrument is a general-purpose laboratory heterodyne consisting of a tuned detector and a two-stage audio-amplifier. A regeneration control is provided so that the detector may be used in either the oscillating or the non-oscillating condition, as the user desires. The heterodyne detector was designed as one of the units of the frequency-measuring system described on page 14. It is also useful as a detector in conjunction with a radio-frequency bridge. Two models are available, one intended for battery operation, the other operating from an a-c line.

SPECIFICATIONS

Frequency Range: Twelve plug-in coils are supplied covering a frequency range of from 90 kc to 7000 kc. Additional coils are available to extend the range downward to 25 kc and upward to 25 Mc. In order to spread out the high-frequency range, two condensers are used, one covering frequencies from 25 kc to 1800 kc and the other covering the higher frequencies from 1500 kc to 25,000 kc. Both condensers are controlled by the same dial, and selection of the proper condenser is made automatically when the coil is plugged in.

Calibration: A calibration is supplied. While this calibration is accurately determined, it is not guaranteed, as the instrument is not intended for use as a calibrated frequency-measuring device.

Controls: On-off switch; tuning, fine and coarse; regeneration control.

Terminals: Three sets of coupling terminals and a pair of telephone terminals are brought out at the rear through multipoint, protected, plug-type connectors. Telephone jack and terminals are also mounted on the panel.

Meters: Detector-plate current.

Mounting: Standard 19-inch relay-rack mounting. Can be supplied in walnut cabinet on special order.

Dimensions: Panel, (length) 19 x (height) 8¾ inches; behind panel, (length) 17¼ x (height) 8½ x (depth) 10¾ inches.

TYPE 619-C HETERODYNE DETECTOR

Power Supply: 105–125 volts, 50–60 cycles. Other voltages and other frequencies on special order only.

Power Input: 25 watts.

Tubes: Furnished with the instrument.

3 56-type detector-amplifiers
1 82-type rectifier

Additional Accessories Required:

Telephones

Accessories Supplied with Instrument:

Vacuum tubes
1—274-M plug
Pilot light, Fuses } with spares
115-volt attachment cord
1—Multipoint connector
12—Plug-in coils

Net Weight: 42½ pounds.

TYPE 619-D HETERODYNE DETECTOR

Power Supply: 6-volt battery terminals for filaments and 90 to 135-volt battery terminals for plates are brought out at the rear through multipoint protected plug connectors.

Tubes: Furnished with the instrument.
3—37-type detector-amplifiers

Net Weight: 35 pounds, without batteries.

Accessories Supplied with Instrument:
Vacuum tubes
1—274-M plug
Pilot light (with spare)
2 Multipoint connectors
12 Plug-in coils

Additional Accessories Required:
Telephones
Batteries

Type	*Description*	*Code Word*	*Price*
619-C	**a-c operated**	MATIN	**$250.00**
619-D	**d-c operated**	MAXIM	**225.00**

Patent Notice 1, 3, 17, page 61.

TYPES 619-H AND -L INDUCTORS

Inductors for use with TYPE 619 Heterodyne Detectors are available to cover frequencies between 25 kc and 25 Mc. Inductors 1L to 7H are supplied with each instrument. Additional inductors can be purchased at the prices indicated below.

Type	*Frequency Range*	*Price*	
		Calibrated	*Uncalibrated*
619-00L	25– 44 kc	**$12.00**	**$9.00**
619- 0L	44– 78 kc	**10.00**	**7.50**
619- 1L	78– 150 kc	**9.75**	**7.50**
619- 2L	150– 290 kc	**8.00**	**5.75**
619- 3L	290– 540 kc	**7.25**	**5.00**
619- 4L	540– 940 kc	**7.00**	**4.75**
619- 5L	940–1750 kc	**6.75**	**4.50**
619- 1H	1.73– 2.08 Mc	**6.75**	**4.50**
619- 2H	2.08– 2.50 Mc	**6.75**	**4.50**
619- 3H	2.50– 3.00 Mc	**6.75**	**4.50**
619- 4H	3.00– 3.60 Mc	**6.75**	**4.50**
619- 5H	3.60– 4.33 Mc	**6.75**	**4.50**
619- 6H	4.33– 5.20 Mc	**6.75**	**4.50**
619- 7H	5.20– 6.25 Mc	**6.75**	**4.50**
619- 8H	6.25– 7.67 Mc	**7.75**	**5.50**
619- 9H	7.67– 9.32 Mc	**7.75**	**5.50**
619-10H	9.32–11.4 Mc	**7.75**	**5.50**
619-11H	11.4 –14.0 Mc	**7.75**	**5.50**
619-12H	14.0 –17.0 Mc	**7.75**	**5.50**
619-13H	17.0 –20.7 Mc	**7.75**	**5.50**
619-14H	20.7 –25.0 Mc	**7.75**	**5.50**

TYPE 691-P1 COIL DRAWER

A coil drawer, for relay-rack mounting, is available for storage of extra coils. The drawer accommodates 20 coils. Relay-rack space of three units (5¼ inches) is required.

Type	*Price*
619-P1	**$35.00**

TYPE 675-H PIEZO-ELECTRIC OSCILLATOR
(A-C Operated)

The TYPE 675-H Piezo-Electric Oscillator is a secondary frequency standard of high accuracy, designed for use as a high frequency standard or for monitoring purposes. The oscillator normally operates with a TYPE 376-J or a TYPE 376-K Quartz Plate (page 52), in the frequency range between 100 and 4000 kc. The guaranteed accuracy of the frequency is 20 parts in a million (0.002%) for the TYPE 376-J Quartz Plate and 30 parts in a million (0.003%) for the TYPE 376-K Quartz Plate. The frequency stability over long periods of time is five parts in a million.

The oscillator is designed for standard 19-inch relay-rack mounting and is completely a-c operated. The internal power supply furnishes filament power at 6 volts and plate supply at 180 volts for any equipment that might be used in conjunction with the oscillator.

Two output circuits are available. One provides a source of fundamental crystal frequency and the other a source of harmonics of the fundamental frequency.

SPECIFICATIONS

Frequency Range: 100 kc to 4000 kc, using TYPE 376-J and TYPE 376-K Quartz Plates.

Accuracy: The guaranteed accuracy is 20 parts in a million (0.002%) for the TYPE 376-J Quartz Plate and 30 parts in a million for the TYPE 376-K Quartz Plate. The frequency stability is 5 parts in a million (0.0005%) over long periods of time.

Quartz Plate: Not furnished with the instrument, which is intended for use only with TYPE 376-J and TYPE 376-K Quartz Plates. For quartz plate specifications see page 52.

Temperature Control: The temperature-control system is identical with that used in the TYPE 747-A Temperature-Control Box (see page 54).

Accuracy of Temperature Control: The unit will control the temperature of the inner space to within ±0.1°C. for room temperature changes of ±16°C. (±29°F.).

Operating Temperature: Normally 50 degrees Centigrade, but thermostats for other temperatures can be supplied on special order.

Thermostat: Fixed, or non-adjustable, mercury type. Accuracy of working point, ±0.2°C. Sensitivity, 0.05°C.

Circuit: The oscillator circuit is identical with that employed in the TYPE 475-A Frequency Monitor Oscillator (page 34) and TYPE 575-E Piezo-Electric Oscillator (page 50).

Inductor: One TYPE 575-DP Inductor (page 51) is furnished with one quartz plate. If two quartz plates are used, and the second is outside the frequency range of the coil used with the first, an additional coil at extra cost is required.

Output: Two output amplifiers are provided, one to pass the crystal fundamental frequency and one for producing harmonics of the crystal frequency. Either or both may be used as desired.

Power Supply: 105–125 volts, 50–60 cycles. Other voltages or other frequencies on special order only. Provision is made through a multipoint connector for obtaining power supply (both filament and plate) for external devices.

Power Input: 45 watts, with heat off; 125 watts with heat on.

Controls: Power supply ON-OFF switch; heat ON-OFF switch; line input voltage control; crystal selector switch; crystal oscillator tuning condensers, fine and coarse tuning.

Meters: Filament and plate voltage; crystal oscillator plate current.

Tubes: Furnished with the instrument.
1—77-type crystal oscillator
2—76-type amplifiers
1—83-type rectifier

Mounting: Standard 19-inch relay-rack mounting. Can be supplied in walnut cabinet on special order.

Accessories Supplied with Instrument:
Vacuum tubes
Thermostat
Thermometer
Pilot lights, Fuses, Fusible link } with spares
110-volt attachment cord
1 TYPE 575-DP Inductor
2 Multipoint connectors

Additional Accessories Required:
TYPE 376 Quartz Plate

Dimensions: Panel, (length) 19 x (height) 17½ inches; behind panel, (length) 17¼ x (height) 17¼ x (depth) 11¾ inches.

Net Weight: 65 pounds.

Type	*Code Word*	*Price*
675-H	AVOWD	**$315.00**

Patent Notice 1, 3, 8, 9, 12, 17, page 61.

TYPE 675-L PIEZO-ELECTRIC OSCILLATOR (A-C Operated)

The TYPE 675-L Piezo-Electric Oscillator is a secondary frequency standard of high accuracy intended for use primarily in the laboratory. The oscillator normally operates with a TYPE 676-A (50-kc) or a TYPE 476-A (100-kc) Quartz Bar (pages 54 and 53), although other crystal frequencies between 50 kc and 100 kc can be

obtained by special order. When used with the above crystals, the absolute guaranteed accuracy of the frequency is 20 parts in one million (0.002%). The frequency stability over long periods of time is five parts in one million.

The oscillator is designed for standard relay-rack mounting and is completely a-c operated. The internal power supply furnishes filament and plate supply for any equipment that might be used in conjunction with the oscillator, such as multivibrators. The TYPE 675-L Piezo-Electric Oscillator is used in the CLASS C-10 Standard-Frequency Assembly (page 27).

Two output circuits are available. One provides a source of fundamental crystal frequency and the other a source of harmonics of the fundamental frequency.

SPECIFICATIONS

Frequency Range: 50 kc or 100 kc, using the TYPE 676-A or TYPE 476-A Quartz Bar, respectively.

Accuracy: The absolute accuracy is ±20 parts in one million (0.002%). The frequency stability is ±5 parts in one million (0.0005%) over long periods of time.

Quartz Bar: Not furnished with the instrument, which is intended for use only with a TYPE 476-A (100 kc) or a TYPE 676-A (50 kc) Quartz Bar (pages 53 and 54). Other crystal frequencies may be obtained by special order.

Temperature Control: The temperature control system is identical with that used in the TYPE 747-A Temperature-Control Box (see page 54).

Accuracy of Temperature Control: The unit will control the temperature of the inner space to within ±0.1 degree Centigrade for room temperature changes of ±16 degrees Centigrade (±29 degrees Fahrenheit).

Operating Temperature: Normally 50 degrees Centigrade, but thermostats for other temperatures can be supplied on special order.

Thermostat: Fixed, or non-adjustable, mercury type. Accuracy of working point, ±0.2°C. Sensitivity, 0.05°C.

Crystal Oscillator: Similar to the TYPE 690-B Piezo-Electric Oscillator (page 28).

Output: Two output amplifiers are provided, one to pass primarily the crystal fundamental frequency (for the control of multivibrators, etc.) and the other arranged in a harmonic-producing circuit for obtaining harmonics of the crystal frequency for measurement purposes. Either or both may be used as required.

Power Supply: 105–125 volts, 50–60 cycles. Other voltages or other frequencies on special order only. Provision is made through a multipoint connector for obtaining power supply (both filament and plate) for three TYPE 692 Multivibrators or for two TYPE 692 Multivibrators and one TYPE 693 Syncro-Clock and Amplifier unit.

Power Input: 45 watts with heat off; 125 watts with heat on.

Controls: Power supply ON-OFF switch; heat ON-OFF switch; line input voltage control; crystal oscillator frequency adjustment condenser; incremental condenser with push-button switch.

Meters: Filament voltage; crystal oscillator plate current; plate voltage.

Tubes: Furnished with the instrument.

1—77-type crystal oscillator
2—76-type amplifiers
1—83-type rectifier

Mounting: Standard 19-inch relay-rack mounting. Can be supplied in walnut cabinet on special order.

Accessories Supplied with Instrument:

Vacuum tubes
Thermostat
Thermometer
Pilot light, Fuses, Fusible link } with spares
110-volt attachment cord
Multipoint connectors

Additional Accessories Required:

Quartz bar

Dimensions: Panel, (length) 19 x (height) 17½ inches; behind panel, (length) 17¼ x (height) 17¼ x (depth) 11¾ inches.

Net Weight: 65 pounds.

Type	*Code Word*	*Price*
675-L	AWAIT	**$315.00**

Patent Notice 1, 3, 8, 9, 12, 14, 17, page 61.

TYPE 575-E PIEZO-ELECTRIC OSCILLATOR

The TYPE 575-E Piezo-Electric Oscillator is a secondary frequency standard of high accuracy designed for use in the laboratory or for monitoring purposes. The oscillator normally operates with a TYPE 376 Quartz Plate (page 52). The absolute guaranteed accuracy of the frequency is 20 parts in a million (0.002%) for the TYPE 376-J Quartz Plate, and 30 parts in a million (0.003%) for the TYPE 376-K Quartz Plate. The frequency stability over long periods of time is five parts in a million.

The oscillator circuit is similar to that used in the TYPE 675-H Piezo-Electric Oscillator and the TYPE 475-A Frequency Monitor. The oscillator is mounted on a standard 19-inch relay-rack panel and is intended for use with external power supply.

SPECIFICATIONS

Frequency Range: 100 to 4000 kc using the TYPE 376 Quartz Plate.

Accuracy: The absolute guaranteed accuracy is 20 parts in a million (0.002%) for the TYPE 376-J Quartz Plate and 30 parts in a million (0.003%) for the TYPE 376-K Quartz Plate. The frequency stability over long periods of time is 5 parts in a million (0.0005%).

Quartz Plate: Not furnished with the instrument which is intended for use only with the TYPE 376 Quartz Plate (page 52).

Temperature Control: A terminal plate carrying two sets of jacks for TYPE 376 Quartz Plates is provided within the temperature-controlled space. The temperature-control system is identical with that of the TYPE 747-A Temperature-Control Box (page 54).

Accuracy of Temperature Control: The unit will control the temperature of the inner space to within ±0.1°C. for room temperature changes of ±16°C. (±29°F.).

Operating Temperature: Normally 50°C., but thermostats for other temperatures can be supplied on special order.

Thermostat: Fixed, or non-adjustable, mercury type. Accuracy of working point, ±0.2°C. Sensitivity, 0.05°C.

Crystal Oscillator: The oscillator circuit is a modified form of tuned-grid circuit using a screen-grid tube. A stabilization system is provided to reduce the effect on the frequency of variations in operating voltages and tubes. The proper operating point is determined by adjusting the tuning condenser until the plate current is at a minimum.

Inductor: One TYPE 575-DP Inductor (page 51) suitable for use at the crystal frequency is supplied with each instrument. If two quartz plates are used, and the second is outside the frequency range of the coil used with the first, an additional coil at extra cost is required.

Output: A radio frequency voltage (1 to 2 volts) of the crystal frequency may be obtained from the

terminals marked R. F. OUTPUT on the terminal strip of the instrument. Neither of these posts is grounded within the instrument.

Power Supply: Jack-top binding posts are provided on the terminal strip for connecting (a) filament supply, (b) 135-volt plate supply, and (c) 105–125 volt, 40–60 cycle, a-c or d-c, heater supply. A TYPE 24-A or TYPE 36 tube may be used.

Heater Power Input: 80 watts with heat on.

Controls: Filament-plate ON-OFF switch; heat ON-OFF switch; crystal selector switch; crystal oscillator tuning condensers.

Meters: Plate current and voltage.

Tubes: Furnished with the instrument.
1—36-type crystal oscillator } Specify tube
or 1—24-A-type crystal oscillator } desired.

Mounting: Standard 19-inch relay-rack mounting. Can be supplied in walnut cabinet on special order.

Accessories Supplied with Instrument:
Thermostat
Thermometer
Pilot lights } with spares
Fuses
Fusible link }
110-volt attachment cord
1—575-DP Inductor

Additional Accessories Required:
TYPE 376 Quartz Plate

Dimensions: Panel, (length) 19 x (height) 10½ inches; behind panel, (length) 17½ x (height) 10¼ x (depth) 10 inches.

Net Weight: 30 pounds.

Type	*Code Word*	*Price*
575-E	ADEPT	**$225.00**

Patent Notice 3, 8, 12, page 61.

TYPE 575-DP INDUCTORS

The TYPE 575-DP Inductors are used as tuning inductances in the following instruments:

TYPE 675-H Piezo-Electric Oscillator
TYPE 575-E Piezo-Electric Oscillator
TYPE 475-A Frequency Monitor

When a TYPE 376 Quartz Plate is ordered with one of these instruments, one TYPE 575-DP Inductor is supplied. Additional inductors are available at the prices given below.

Type	*Frequency Range*	*Price*
575-DP2	85– 170 kc	**$12.00**
575-DP3	150– 320 kc	**9.00**
575-DP4	275– 590 kc	**7.00**
575-DP5	500–1100 kc	**5.00**
575-DP6	850–1800 kc	**5.00**
575-DP7	1250–2800 kc	**5.00**
575-DP8	2000–4500 kc	**5.00**
575-DP9	3100–7000 kc	**5.00**
575-DP10	5– 11 Mc	**5.00**
575-DP11	50 kc	**15.00**
575-DP12	30 kc	**15.00**

TYPE 376 QUARTZ PLATE

The TYPE 376-J Quartz Plate and the TYPE 376-K Quartz Plate are intended for use in piezo-electric oscillators as standards of frequency in laboratory measurements and in frequency monitoring installations. Since the high order of frequency stability required in such services is not compatible with high power output from the oscillator, the frequencies of all plates are guaranteed for operation at a low power level. These plates are not sold for use in direct frequency control of radio transmitters. The type of oscillator in which the plate should be operated is also specified because this allows a much closer accuracy guarantee than would otherwise be possible.

The frequencies of the TYPE 376-J and TYPE 376-K are adjusted closely to the ordered frequency, and they are guaranteed to be accurate to within a very few parts in a million.

All plates are manufactured from high grade piezo-electric quartz, free from twinning. The plates are cut by modern optical manufacturing methods and the parallelism of the surfaces and their orientations with respect to the crystallographic axes are held to extremely small tolerances.

SPECIFICATIONS*

Frequency Range: The TYPE 376-K can be made for any frequency in the range between 100 kc and 4000 kc. The TYPE 376-J is supplied only for frequencies between these limits which are multiples of 1 kc.

Accuracy of Adjustment: The frequency of the plate is adjusted until it differs in our laboratory from the ordered frequency by an amount less than the amount given in the column headed "Adjusted Within" in the table.

Accuracy of Calibration: After the frequency of the plate has been adjusted as described in the preceding paragraph, the frequency is accurately measured in terms of standard frequencies from a General Radio CLASS C-21-H Standard-Frequency Assembly (page 24) and the result of this measurement is entered in the calibration certificate.

Certified Accuracy: The certificate mentioned in the preceding paragraph also states the limits within which the frequency is guaranteed to be, as specified in the third column of the table, the one headed "Maximum Deviation from Certified Frequency." This column gives the maximum deviation of the crystal from the certified frequency when the plate and oscillator are operated within the temperature and other operating limits specified.

Frequency Tolerance: To find the amount by which the actual frequency of the plate may differ from the frequency ordered, add the figures in the second and third columns ("Adjusted Within" and "Maximum Deviation"). For example, if a TYPE 376-K Quartz Plate is ordered, the user can rely on its frequencies being within 0.0025% of the frequency which he specified when ordering and within 0.002% of the frequency entered in the certificate of calibration.

Oscillator: The frequency and the frequency stability of a piezo-electric frequency standard

depend upon the design and construction of the oscillator. Hence, the performance of all General Radio quartz plates is specified in a given type of oscillator.

TYPE 376-J and TYPE 376-K Quartz Plates are sold for use only in TYPES 575-E and 675-H Piezo-Electric Oscillators and TYPE 475-A Frequency Monitor.

Mounting: The crystal holder consists of an isolantite base carrying an aluminum cap with a means for adjusting, locking, and sealing the air gap. It is practically dust proof and is fitted with plugs for use in General Radio piezo-electric oscillators.

Dimensions: Base, (width) 2¾ x (depth) 2 x (height) 1¼ inches, over-all.

Net Weight: 1 pound.

Type	*Adjusted Within*	*Max. Deviation from Certified Frequency*	*Temperature*	*Code Word*	*Price*
376-J	0.0001% or 1 cycle of frequency ordered, whichever is smaller.	0.002%	50° ±0.1°C.	AGAPE	**$85.00**
376-K	0.0005% or 5 cycles of frequency ordered, whichever is smaller.	0.002%	50° ±0.1°C.	AFOUL	**85.00**

Credit allowance for returned TYPE 376 Quartz Plates, Serial No. 2438 and higher..... **15.00**

*Before ordering quartz plates, read carefully the above specifications. The Engineering Sales Department will be glad to make suggestions regarding the type of quartz plate required for a specific purpose.

TYPE 476-A QUARTZ BAR and TYPE 476-P1 ADAPTER

The TYPE 476-A Quartz Bar operates at a frequency of 100 kc and is used (with TYPE 476-P1 Mounting) in TYPE 675-L Piezo-Electric Oscillator.

The electrodes are deposited directly on the quartz, the bar is clamped nodally, and baffles are provided to eliminate the effects of high frequency supersonic energy radiated from the ends.

The bar is entirely enclosed and mounted on a base similar to that used on TYPE 376 Quartz Plates.

The TYPE 476-P1 Adapter is necessary when Type 476-A Quartz Bar is used in a TYPE 675-L Piezo-Electric Oscillator. It provides jacks for plugging in the quartz bar and carries an inductor and two condensers for completing the oscillating circuit.

SPECIFICATIONS

Frequency: 100 kc.

Cut: Zero-angle, Curie or X-cut.

Dimensions: TYPE 476-A and TYPE 476-P1, (length) 3¼ x (width) 3¼ x (height) 3 inches, over-all. TYPE 476-A, (length) 2 x (width) 2 x (height) 1 3/16 inches, over-all, exclusive of plug.

Net Weight: TYPE 476-A, 1 pound; TYPE 476-P1, 14 ounces.

Type	*Description*	*Code Word*	*Price*
476-A	**100-kc Quartz Bar**.....	MOCHA	**$95.00**
476-P1	**Adapter**.....	ADAPTORCOP	**20.00**

Patent Notice 19, page 61.

TYPE 676-A QUARTZ BAR AND MOUNTING

The TYPE 676-A Quartz Bar is intended for use in TYPE 690-B and TYPE 675-L Piezo-Electric Oscillators. The mounting base includes the necessary inductor and condensers for use in these oscillators. The standard model has a frequency of 50 kc; other frequencies between 50 kc and 30 kc can be supplied on special order.

The electrodes are deposited directly on the surface of the quartz, eliminating the usual series air gap. Rigid clamping at a nodal point and the use of air baffles at the end reduce to a minimum the effect of the mounting on the frequency. The bar is zero-angle cut and vibrates along its longest dimension in a direction at right angles to the electric axis.

SPECIFICATIONS

Frequency: 50 kc.

Orientation: Zero-angle, Curie or X-cut.

Dimensions: (Length) 3¼ x (width) 3¼ x (height) 3⅜ inches, over-all.

Net Weight: 1⅛ pounds.

Type	*Code Word*	*Price*
676-A	PIEZOMUSH	**$145.00**

Patent Notice 19, page 61.

TYPE 747-A TEMPERATURE-CONTROL BOX

The TYPE 747-A Temperature-Control Box is designed for use in controlling the temperature of quartz plates in order to assure constant frequency.

A terminal plate carrying two sets of jacks for TYPE 376 Quartz Plates is provided within the temperature-controlled space. Choice of the quartz plate which is in circuit is made by a switch mounted on the panel. Within the cabinet are placed a balsa-wood insulating layer, distributed heaters (placed on all six faces of the interior assembly), an aluminum distributing layer, an asbestos attenuation layer, and a second aluminum distributing layer which forms the wall of the temperature-controlled space. A thermometer graduated in 0.5°C. divisions from 40° to 60°C. is mounted behind a slot in the panel and is illuminated by the heat-control indicating lamp. This thermometer indicates the air temperature of the inner space. The temperature-control system operates on 115 volts, ac or dc.

This instrument can be supplied mounted in a cabinet or on a standard 19-inch relay-rack panel. When supplied for relay-rack mounting, space is available at the right of the temperature-control box for the construction of oscillating circuits or other associated circuit elements. The terminals for the quartz plate are brought out at the right-hand side of the box, making it convenient to attach leads to other circuits and at the same time reducing the length of leads necessary.

SPECIFICATIONS

Accuracy of Temperature Control: The unit will control the temperature of the inner space to within ±0.1°C. for changes in room temperature of ±16°C. (±29°F.). Where the crystal is operated at a power level so high that it generates heat, the temperature can be held to within the same limits if the heat generated by the crystal remains constant.

Operating Temperature: Normally 50°C., but thermostats for other temperatures can be supplied on special order.

Thermostat: Fixed, or non-adjustable, mercury type. Accuracy of working point ±0.2°C. Sensitivity 0.05°C.

Power Supply: 105–125 volts, 40–60 cycles, or 105–125 volts dc. Other voltages or other frequencies on special order only.

Power Input: 80 watts with heat on.

Controls: Heat ON-OFF switch; crystal selector.

Terminals: Quartz plate terminals are brought out on the side of instrument.

Meters: Thermometer.

Mounting: Standard 19-inch relay-rack mounting or walnut cabinet.

Accessories Supplied with Instrument:

1—274-M plug
Pilot light, Fuses, Fuse links } with spares
1—115-volt attachment cord

Dimensions: TYPE 747-AM, (length) 13¼ x (height) 11⅝ x (depth) 13½ inches, over-all.

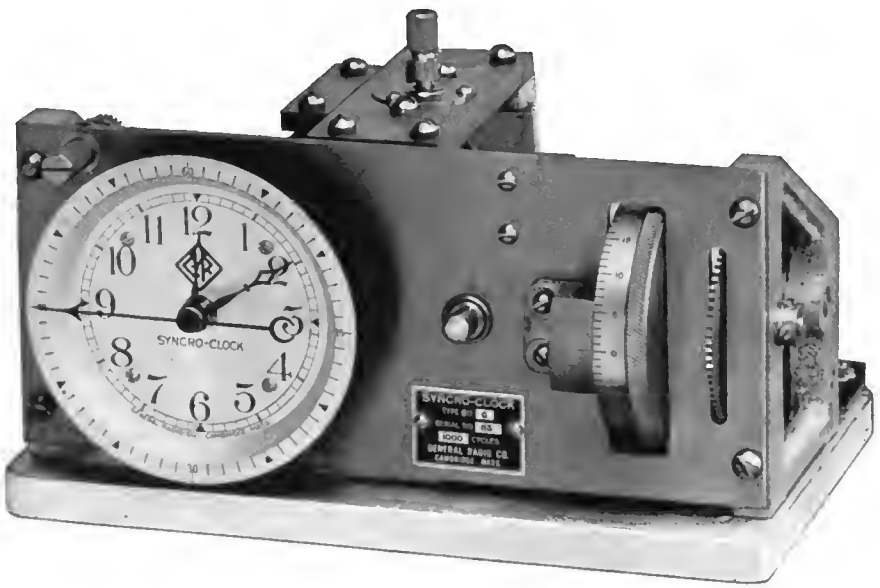
TYPE 747-AR: Panel, (length) 19 x (height) 10½ inches; behind panel, (length) 11½ x (height) 9⅝ x (depth) 10 inches.

Net Weight: TYPE 747-AM, 31¾ pounds; TYPE 747-AR, 29 pounds.

Type	*Description*	*Code Word*	*Price*
747-AM	**Cabinet mounting**	BURLY	**$150.00**
747-AR	**Relay-rack mounting**	BATHE	**150.00**

Patent Notice 8, page 61.

TYPE 611 SYNCRO-CLOCK



In a Class C-21-H Standard-Frequency Assembly the synchronous-motor-driven clock is the counting device for totalizing the number of vibrations of the crystal in any given time interval. When driven by a stable oscillator, this device may be used as a source of precisely determined time intervals and, conversely, when its indication is compared with standard time, a measure of the driving frequency is obtained.

The TYPE 611 Syncro-Clocks are designed to operate from the output circuit of a low-power vacuum tube. The motor is of the impulse type, and since no accelerating torque is provided in the system, the motor must be brought up to synchronous speed. A 60-cycle, 115-volt motor under control of a push-button switch on the face of the instrument is provided for this purpose. Clocks are normally supplied to keep true time on an exactly 1000-cycle source.

The micro-dial attachment consists of a rotary contact closing once a second, the instant of contact (or phase) being adjustable over a range of one second. It is used in making time comparisons and also for supplying impulses at one-second intervals.

SPECIFICATIONS

Frequency: Clocks are normally supplied to keep true time when the frequency is exactly 1000 cycles.

Power Consumption: One 41-type or 45-type tube supplies sufficient power.

Mounting: Cabinet-mounted models (for use on the laboratory bench) and panel-mounting models are available, but only the panel-mounting type with a micro-dial is regularly carried in stock.

Dimensions: TYPE 611-C, (width) 9⅜ x (depth) 6 x (height) 6 inches.

Net Weight: TYPE 611-C, 14 pounds.

Type	*Description*	*Code Word*	*Price*
611-C	**Panel Mounting with Micro-Dial**	SYNCROGOOD	**$220.00**

TYPE 480 RELAY RACK

This rack is intended for mounting standard 19-inch panels whose heights are integral multiples of 1¾ inches. Racks of this type have been in use in telephone plants for many years, and they are fast becoming standard in laboratories for mounting apparatus. Two sizes are available.

SPECIFICATIONS

Construction: Steel frame with welded joints. Both models have provision for bolting them to the floor or table, but they are stable enough to stand without fastening for all ordinary service.

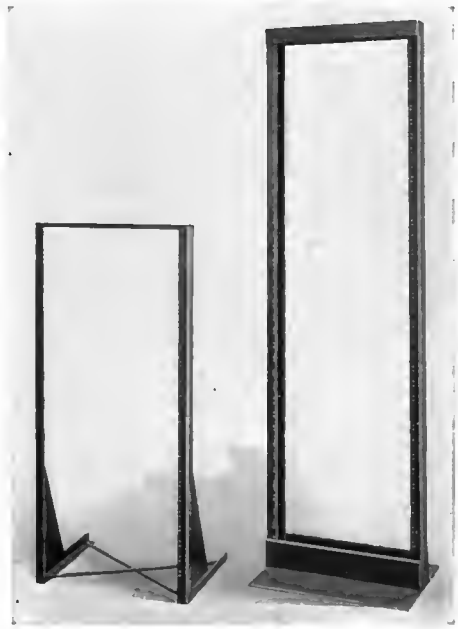
Drilling: Standard drilling for 19-inch relay-rack panels is employed. Holes are tapped and cleaned for a 10–32 panel-mounting screw (TYPE 738-D).

Accessories: Panel-mounting screws, panel-protecting washers, and bridle rings for cabled wiring are supplied.

Dimensions: TYPE 480-A: Frame, (height) 69⅛ x (width) 20 x (depth) 3 inches, over-all. Base, (width) 20 x (depth) 15 inches. Panel-mounting space, 63 inches or 36 "rack units."

TYPE 480-B: Frame, (height) 44 x (width) 20 x (depth) 1½ inches, over-all. Base, (width) 20 x (depth) 15 inches. Panel-mounting space, 43¾ inches or 25 "rack units."

Net Weight: TYPE 480-A, 94 pounds. TYPE 480-B, 20 pounds.



Left: TYPE 480-B; *right:* TYPE 480-A

Type	*Panel Space* *Inches*	*Rack Units*	*Code Word*	*Price*
480-A	63	36	NEEDY	$40.00
480-B	43¾	25	NEGRO	15.00

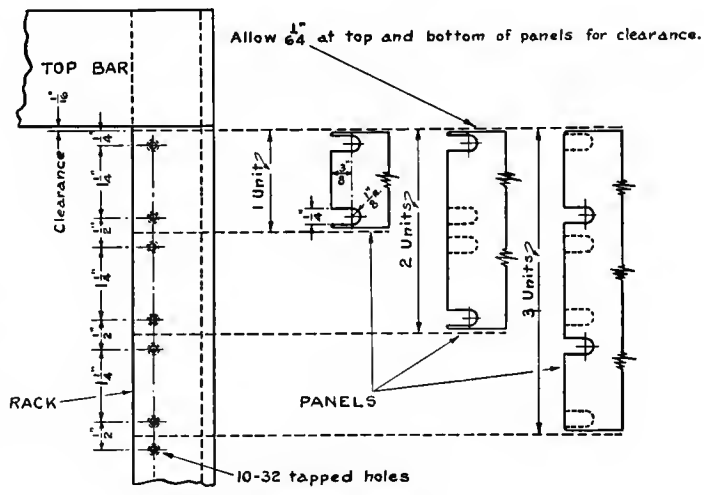
NOTES ON LAYING OUT RELAY-RACK PANELS

1. Make panel height a multiple of 1¾ inches less 1/32 inch for clearances.

2. Both top and bottom edges of a properly mounted panel will, neglecting clearances, always fall half way between a pair of holes spaced ½ inch apart on the rack.

3. It is seldom necessary to cut all the possible mounting-screw slots in a panel, but it can be done if desired.

4. Any panel laid out to fit the rack will also fit if the panel is turned end-for-end or back-for-front.



Note: Clearance between vertical supports on rack 17½ inches.

INDEX BY TYPE NUMBER

INDEX BY TITLE

SUGGESTIONS FOR ORDERING

ORDER BY TYPE NUMBER

Always order by catalog type number and whenever possible mention ranges or other significant specifications as protection against misunderstanding.

Make sure to include orders for any calibrations or accessories which cannot be supplied unless we have the instrument.

SHIPPING INSTRUCTIONS

Unless specific instructions accompany the order we shall use our best judgment as to the method of shipment.

All prices are F.O.B. Cambridge, Massachusetts. There is no domestic packing charge and no charge for shipping cases.

TERMS

Net 30 days. Unless credit has already been established we make all shipments C.O.D.

When cash accompanies the order, we pay transportation charges to any point in Canada and the continental United States (except Alaska).

REMITTANCES

Should be made payable at par in Boston or New York funds.

QUANTITY DISCOUNTS

When 10 or more identical items are ordered at the same time for a single shipment, the following quantity discounts are allowed:

10–19	5 per cent
20–99	10 per cent
100 or more	Special discounts quoted on request.

NO TRADE OR EDUCATIONAL DISCOUNTS

Our prices are made on a direct-to-consumer basis which permits of no discounts except the above stated quantity discounts.

PRICE CHANGES

All prices are subject to change without notice. Formal quotations remain open for 30 days.

TAXES

As the apparatus and parts furnished by us, as sold by us, are not subject to the manufacturers' excise tax imposed on certain radio items under Section 607 of Title IV of the Revenue Act of 1932, no tax has been included in the price. If any of these component parts are used by a "manufacturer, producer, or importer" and in a taxable manner, as defined in this Revenue Act, such "manufacturer, producer, or importer" must see that the requisite tax is paid on them. Tubes on which a tax is payable have had this tax paid and the prices given include this tax. Prices are subject to revision as to any sales or excise taxes, either Federal or local, which may hereafter be imposed.

SHIPMENTS TO GENERAL RADIO

When returning instruments for repair, recalibration, or for any other reason, please ask our Service Department for shipping instructions and our RETURNED APPARATUS tags.

REPAIR PARTS

When ordering repair parts, be sure to describe carefully the parts required and give the type number and serial number from the panel of the instrument.

TELEGRAPH AND CABLE ORDERS

We have direct telegraph printer connections with Postal and Western Union for the prompt handling of messages.

Use Bentley's code and the code words accompanying each catalog description. Our cable address is GENRADCO BOSTON.

SALES AGENCIES

The items listed in this catalog are of such a nature that they are best distributed on a direct-from-manufacturer-to-consumer basis. Therefore, with the exception of a stock of parts for local distribution in New York City carried by Leeds Radio Company of 45 Vesey Street, our instruments are not sold by dealers or brokers.

NEW YORK OFFICE

An engineering office is maintained at 90 West Street, New York City, where technical information regarding our apparatus may be obtained by those who find it more convenient to telephone or call at that office than at Cambridge. No stock is held at the New York office.

Sales offices are maintained on the Pacific Coast at 274 Brannan Street, San Francisco, and at 555 South Flower Street, Los Angeles. Small stocks are maintained at these locations.

Although our domestic sales are made on a direct-to-the-consumer basis, we have arranged with numerous foreign agents for the distribution of our products outside of the United States.

WARRANTY

Our apparatus is so largely covered by the Scientific Apparatus Makers' Code of Fair Trade Practice that their uniform warranty has been made applicable to all of our products. This warranty is:

"We warrant each new instrument manufactured and/or sold by us to be free from defects in material, workmanship, and design; our obligation under this warranty being limited to repairing or replacing any instrument or part thereof which shall, within one year after delivery to the original purchaser, prove by our examination to be thus defective."

This warranty supersedes all other guarantees on our instruments, unless otherwise specified.

OTHER GENERAL RADIO PUBLICATIONS

In addition to this catalog we publish a monthly magazine, *The General Radio Experimenter*, for free distribution among interested persons. It contains technical and semi-technical engineering articles which are contributed, for the most part, by our engineering staff.

There is no subscription fee. To be placed on the mailing list merely address a request to us containing your name, mailing address, and business affiliation.

PATENTS

Many of our products are manufactured and sold under United States Letters Patent owned by the General Radio Company or under license grants from other companies. To simplify the listing of these patents they are given here in a single list and referred to at each instrument only by appropriate reference number.

1. Vacuum-tube amplifier devices, electrical wave filters, and vacuum-tube oscillators are licensed by Electrical Research Products, Inc., under all United States Letters Patent owned or controlled by American Telephone and Telegraph Company, or Western Electric Company, Inc., and any or all other United States patents with respect to which Electrical Research Products, Inc., has the right to grant a license, solely for utilization in research, investigation, measurement, testing, instruction, and development work in pure and applied science, including engineering and industrial fields.

2. Patent 1,871,886.

3. Patent 1,542,995.

4. Patent 1,707,594.

5. Patent 1,901,343.

6. Patent 1,901,344.

7. Patent 1,944,315.

8. Patent 1,967,185.

9. Patent applied for.

10. Patent 1,525,778.

12. Licensed under all patents and patent applications of Dr. G. W. Pierce pertaining to piezo-electric crystals and their associated circuits.

13. Licensed under Hazeltine and Latour Designs and Patents for scientific measurement and test purposes only.

14. Patents 1,931,530; 1,943,302; 1,955,739.

15. Licensed under designs and patent applications of Dr. Harold E. Edgerton.

16. Patent 1,790,153 and other patents, covering electrical discharge devices and circuits with which said devices may be used, owned by the General Electric Company or under which it may grant licenses.

17. Patents 1,713,146 and 1,744,675.

18. Patent 1,983,447.

19. Patent 1,967,184.

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